PREFEASIBILITY REPORT FOR THE PATTENGAIL DAM BEAVERHEAD COUNTY, MONTANA

LEGISLATIVE SUMMARY PRESENTED TO
FORTY-EIGHTH MONTANA LEGISLATURE

MONTANA DEPARTMENT OF NATURAL RESOURCES & CONSERVATION

WATER RESOURCES DIVISION

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PREFEASIBILITY REPORT FOR THE PATTENGAIL DAM

BEAVERHEAD COUNTY, MONTANA

Recommendations presented to
the Forty-eighth Montana Legislature
in response to House Bill 709 of 1981

January 1983

Water Resources Division
Department of Natural Resources and Conservation

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SUMMARY

Water shortages in southwestern Montana's Big Hole River Basin have been a problem since the turn of the century. Each year irrigators in the upper basin suffer water shortages; in both the upper and lower basins, there is not enough water to irrigate new lands. Periodic dewatering also adversely affects the river's blue-ribbon fishery.

Recognizing these problems, the 1979 Montana Legislature directed the Department of Natural Resources and Conservation (DNRC) to study possible sites for water storage in the Big Hole River Basin. After a comparative evaluation of sites, Pattengail Creek, a tributary of the Wise River, was selected as the site with the best potential for a storage facility. In passing HB 709, the 1981 Montana Legislature authorized and funded $75,000 for a technical and economic prefeasibility study of a dam on Pattengail Creek.

This report, prepared by DNRC in response to HB 709, contains the results of the study of tributary storage on Pattengail Creek and DNRC's recommendations for legislative action. Approximately $40,000 of the appropriation was used for this study.

Water Storage on Pattengail Creek

A dam on Pattengail Creek would store water from spring and early summer runoff and would release it during late summer low-flow periods. The stored flow would provide additional water for agricultural and instream uses. The dam site, located in Beaverhead County, is less than a mile from the creek's confluence with the Wise River and about 11 miles from the mainstem of the Big Hole River.

The dam would have a total storage capacity of about 12,000 acre-feet and a usable capacity of slightly less than 11,000 acre-feet. The firm annual yield (amount of water available in all years) would be 10,140 acre-feet.

This study of water storage on Pattengail Creek included the following: 1) an analysis of the site's geologic suitability for dam construction; 2) an engineering analysis of the dam and reservoir site; and 3) an economic and financial analysis of the project. The study also included a preliminary examination of using water rights/water management as an alternative approach to resolving water shortages in the Big Hole River Basin.

Conclusions

1. The earthfill dam originally proposed for the Pattengail Creek site by a consultant for DNRC -- and recommended in the report prepared for the 1981 Legislature -- is not feasible, largely because of the lack of sufficient dam construction materials within an economic hauling distance of the site.

2. Based on current information, a safe structure can be constructed on Pattengail Creek. This structure, a rockfill dam, would cost approximately $14.4 million (July 1982 dollars), which is three times the consultant's original estimate for an earthfill dam ($4.2 million in July 1982 dollars).

3. If a final design for a dam at Pattengail Creek is to be developed, additional technical studies including a detailed seismic evaluation of site conditions and subsurface investigations in the area of the dam's right abutment must be conducted.

4. The rockfill dam that is technically feasible at the Pattengail site is not economically feasible under present conditions. Water from this structure would cost approximately $110 per acre-foot. Maximum return from this storage is approximately $44 per acre-foot, resulting in a net loss of $66 per acre-foot.

5. Water rights/water management is a potential alternative solution to the periodic water shortages in the Big Hole River Basin. Further investigation is necessary to determine the practicality of this approach.

Recommendations

1. The Pattengail Creek dam site should not at this time receive further consideration as a viable solution to the recurring water shortages in the Big Hole River Basin.

2. If a water rights/water management approach to resolving water shortages in the Big Hole River Basin is pursued, the adjudication of water rights in the basin should be given priority by the courts.

Chapter I

INTRODUCTION

Water shortages have plagued the Big Hole River Basin in southwestern Montana since the early part of this century. Irrigators in the upper basin suffer water shortages each year; in both the upper and lower basins, new lands cannot be irrigated because there isn't enough water to do so. Periodic dewatering also threatens the fishery in the lower blue-ribbon reach of the river.

Recognizing these problems, the 1979 Montana Legislature directed the Department of Natural Resources and Conservation (DNRC) to conduct a water demand survey in the Big Hole and Jefferson river basins and to study tributary storage sites that could supply water to relieve shortages.

A report discussing the results of that study -- Water Storage in the Big Hole: A Recommendation (DNRC 1981) -- was submitted to the 47th Montana Legislature in 1981. The report included data on existing and potential irrigation requirements in the basin, as well as instream flow and municipal needs. Water shortages were assessed and potential solutions were explored.

From these data, it became apparent that tributary storage showed the greatest potential for alleviating periodic water shortages in the Big Hole River Basin. This alternative was selected after a preliminary comparison with mainstem storage, ground water development, water conservation, and water rental. After a comparative evaluation of 22 possible tributary storage sites, a site on Pattengail Creek was selected for further study. Storage at Pattengail Creek, a tributary of the Wise River, would provide water for instream use, irrigation, and flood control (DNRC 1981).

As a part of its 1981 report, DNRC recommended that the first step toward developing water storage on Pattengail Creek should be a detailed geologic, engineering, and economic feasibility study of the dam and storage site. In passing House Bill 709, the 1981 Legislature authorized this study, which was funded through the Renewable Resources Development Program. This report, prepared for the 48th Legislature, contains the results of the study and the department's recommendations for legislative action.

PURPOSE OF THE STUDY

This study was designed to investigate the geologic, engineering, and economic feasibility of constructing a dam on Pattengail Creek. The dam would store water from spring and early summer runoff and release it during water shortages in August and September. The stored flow would provide additional water to irrigators and would enhance instream flows for fisheries, wildlife habitat, water quality, and recreation -- primarily fishing and boating.

The study included: 1) an analysis of the site's geology to determine its suitability for dam construction; 2) an engineering analysis of the dam structure and reservoir site; and 3) an economic assessment, which weighed the costs of building the dam against the benefits that might be derived from it.

DESCRIPTION OF THE PATTENGAIL CREEK SITE

Pattengail Creek is a tributary of the Wise River, which flows into the Big Hole River just east of the community of Wise River in Beaverhead County, Montana (see figure I-1). At the dam site, the creek meanders through a glaciated valley covered by a peaty bog and riparian plant species. The mountains surrounding the valley form part of the Pioneer range.

In 1901 the Montana Power Company built a dam at the site. After several years of use, the dam was breached and the company abandoned it. Local ranchers then filled the cut in the dam and used the reservoir to store water for irrigation. In 1927 the dam was overtopped by flood waters which washed out one end of the dam and caused severe damage to property downstream. Since then the site has remained unused.

The dam site under study is located across a natural constriction of the lower Pattengail Creek valley, slightly less than a mile upstream from where that valley meets the Wise River. The site is about 11 miles southwest of the town of Wise River. The dam would be in the SW1/4 of Sec. 10, T.2S., R.12W. The reservoir would cover about 400 acres of public land in parts of Sections 8, 9, 10, 16, 17, and 18, T.2S., R.12W. This land, part of the Beaverhead National Forest, is managed by the U.S. Forest Service.

The reservoir would have a total storage capacity of about 12,000 acre-feet and a usable capacity of slightly less than 11,000 acre-feet. The firm annual yield (amount of water available in all years) would be 10,140 acre-feet. Chapter II contains a more detailed description of the site.

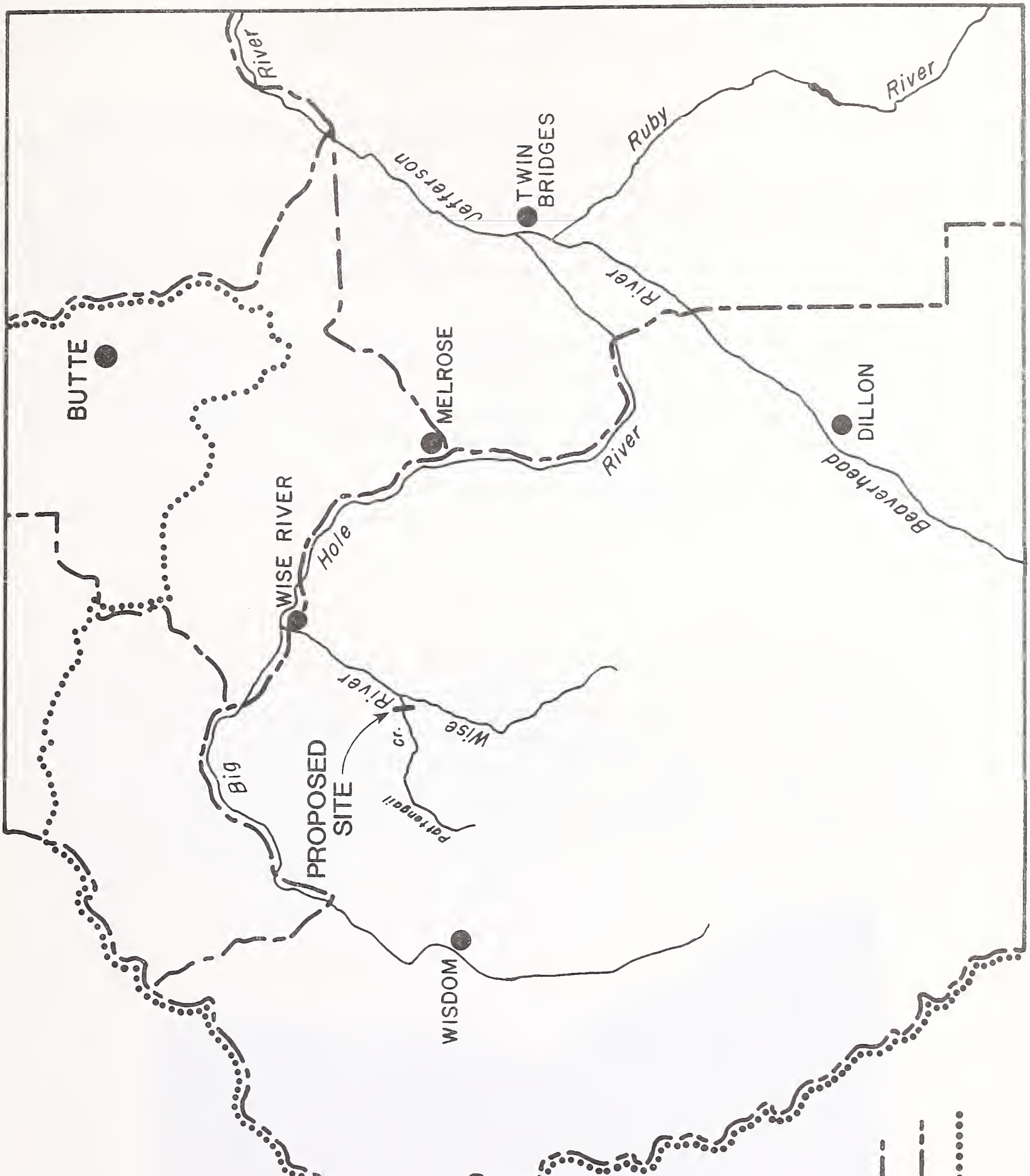


FIGURE I-1 BIG HOLE RIVER BASIN

Chapter II

GEOLOGIC ANALYSIS OF THE PATTENGAIL SITE

The investigation of the geologic conditions at the Pattengail Creek dam site took place in two phases.

The first phase included a review of the existing geologic data on the site and a visit to the site in October 1981. The existing data indicated that more sophisticated studies were necessary to evaluate the site's geologic suitability for dam construction.

The second phase of the investigation, conducted during the summer of 1982, consisted of inspecting more of the site's surficial geology, core drilling five holes in the area of the dam axis, and digging eight test pits for materials analyses in a potential borrow area about 1/2 mile east of the dam site.

Geologic logs of all drill holes and test pits, as well as laboratory test data, are presented in appendix A.

NATURAL SETTING

In the reservoir area, Pattengail Creek is a slow moving, meandering stream with ponds created by numerous beaver dams (figures II-1 and II-2). The glaciated valley floor has been leveled by the accumulation of lakebed deposits and is now almost entirely covered by a peaty bog. Willows line the creek banks and conifers and aspens cover most of the talus-buried slopes. Rock outcrops occur part way up on the adjacent mountain sides and the rounded tops of many of the mountains are entirely devoid of woody vegetation.

Figure II-1. Pattengail Creek site.

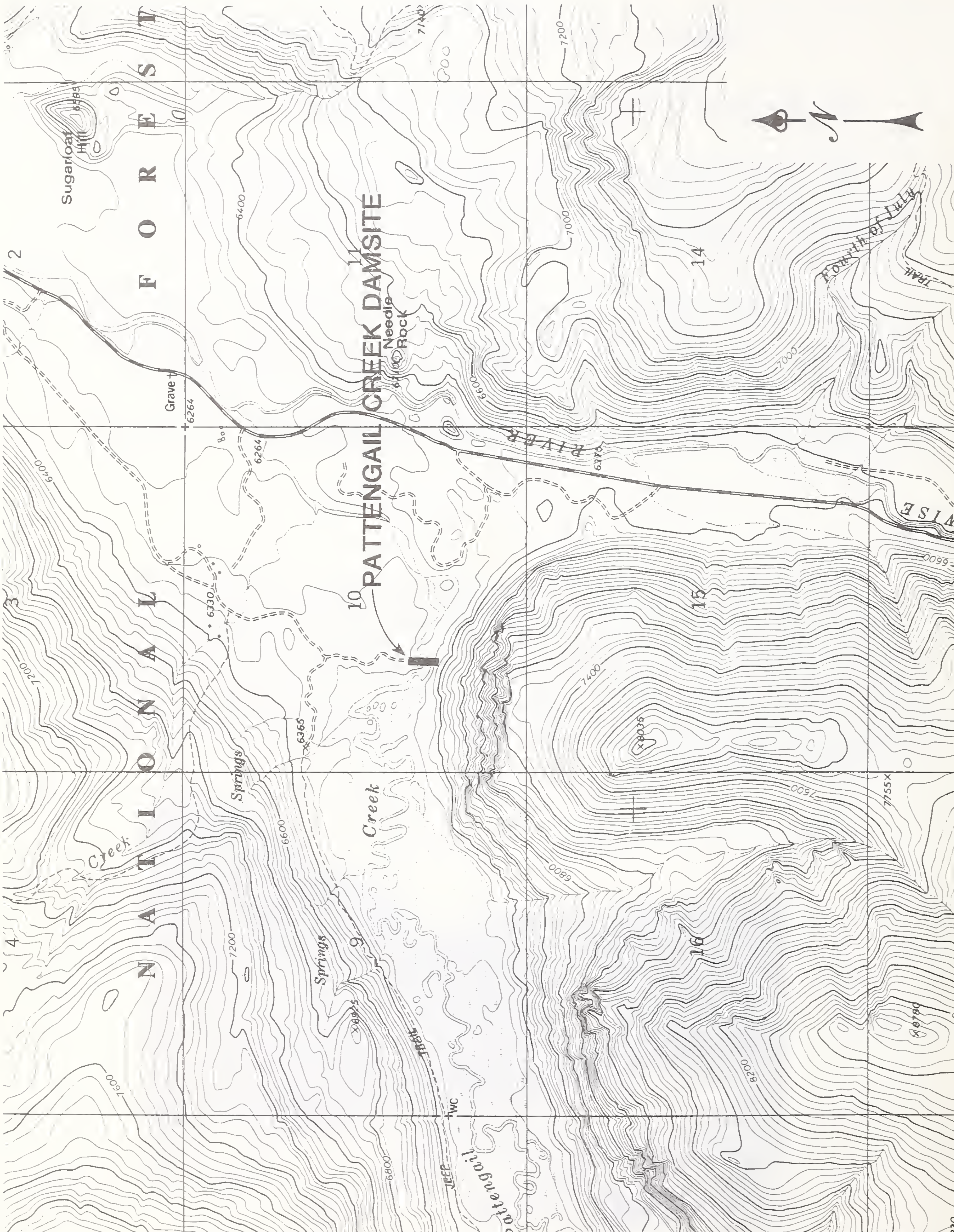


FIGURE II-2 PATTENGAIL CREEK SITE

The area is prime habitat for moose, elk, deer, beaver, and smaller game and nongame animals. The creek contains an excellent fishery, particularly in its upper reaches. Brook trout, with lesser numbers of rainbow trout, cutthroat trout, and whitefish, are found in the creek.

The principal values of the area are wildlife habitat, watershed protection, and timber production. Although the potential for minerals development in the area is not precisely known, exploratory drilling for molybdenum ores was recently conducted in the valley's upper reaches. Recreational uses are primarily hunting, fishing, camping, and hiking. The remote area is served only by an unimproved four-wheel-drive trail off the Wise River road.

EXISTING STRUCTURES

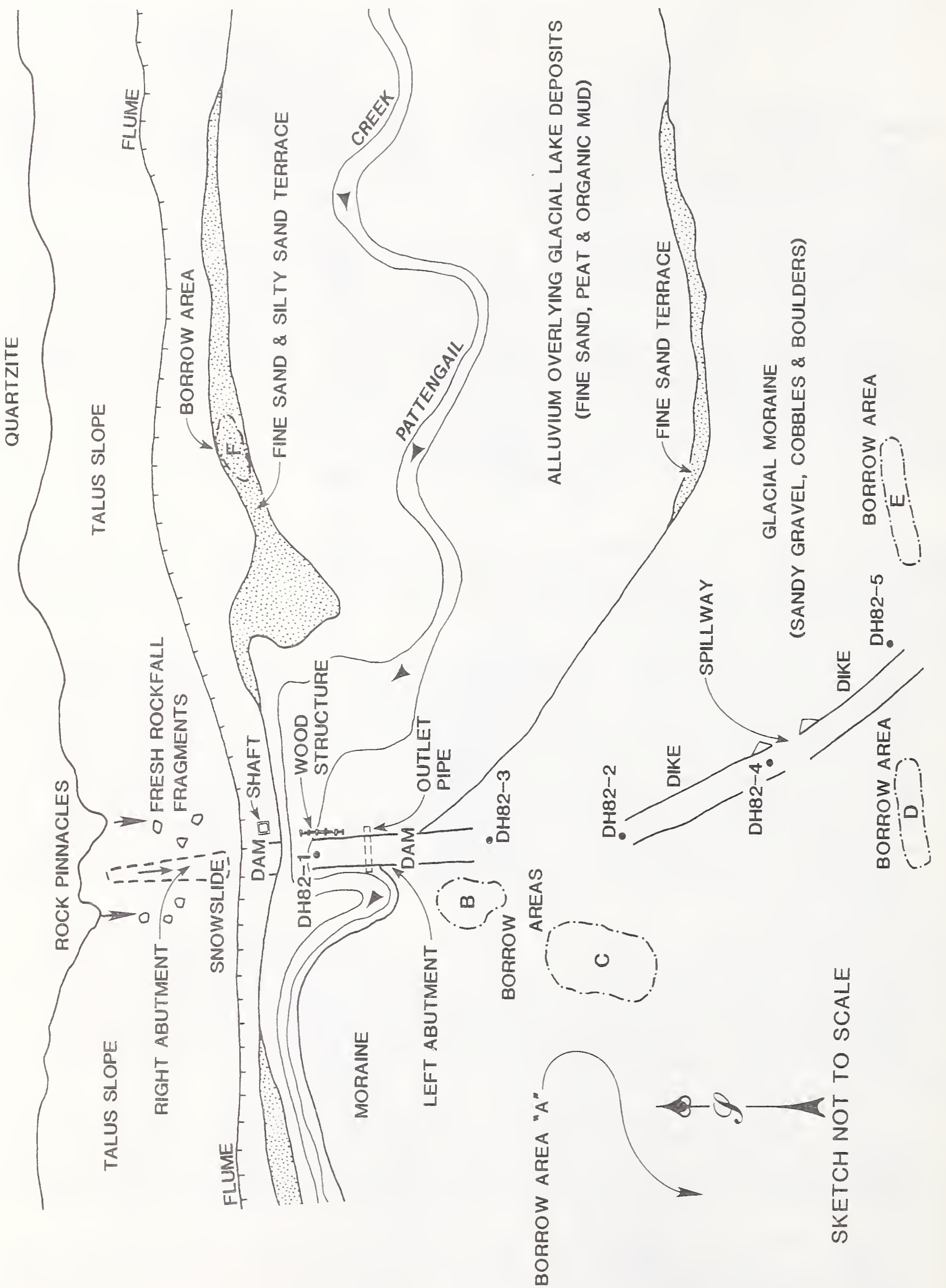
Although the Pattengail Creek site was used for water storage in the past, records on such use are scarce. Thus, it is difficult to determine the precise function of the man-made structures existing at the site.

The Montana Power Company built a dam on Pattengail Creek in 1901. This structure was damaged during spring runoff in 1927; a 200-foot section near the right abutment was washed away, leaving only 300 feet of the original structure intact. The top of the remaining section is about 40 feet above the creek level. The top of the old dam is about 15 feet wide. An iron pipe (about 3 feet in diameter) and a burned wooden gate structure below the pipe are the only visible outlets. These outlets are located slightly to the left of the maximum section. A wooden structure, probably a diversion or cutoff wall, parallels the upstream toe of the dam (see figure II-3).

The old dam is composed of sandy gravel containing a large portion of angular quartzite and igneous rock fragments. Less than 5 percent of the embankment material is estimated to be nonplastic fines. Limited digging in the embankment revealed numerous small voids, and drilling encountered no impermeable core material. The upstream face of the dam is not riprapped.

A long, low dike extends northward through the trees from a slight knoll to the north of the left dam abutment. This dike prevented water from the old reservoir from escaping through topographic lows on the north side of the valley. A 25-foot-wide spillway with a wooden control structure cuts through this dike.

The dike is composed of sand and silty sand; the highest sections probably also contain sandy gravel similar to that found in the dam embankment. The dike is riprapped only at the emergency spillway inlet.



SOURCE: U. S. Bureau of Reclamation

FIGURE II-3 GEOLOGIC FEATURES AND EXISTING STRUCTURES

A collapsed shaft lies at the toe of a talus slope approximately 75 feet upstream from the dam's right abutment. It appears that the shaft was dug before the original dam was constructed so that the builders could determine the depth of talus in the right abutment.

The remains of a wooden flume, or possibly two separate flumes, cross the talus slope above the right abutment and parallel the valley both upstream and downstream from the dam. The upstream portion was traced for about 1/2 mile; it continued upstream from that point. Although the downstream portion of the flume was not followed to its source, it apparently ties into an old diversion ditch just west of the present Wise River road. Previous references to the dam indicate that "a diversion ditch 1 1/4 miles long, capacity 50 second-feet, was used to divert Wise River water into the reservoir" (Perry 1934). The downstream portion of the flume is evidently an extension of the diversion ditch. It is unlikely, however, that the diversion flume would have extended much past the upstream side of the dam. Thus, the upstream portion of the flume may have served an entirely different function.

PREVIOUS GEOLOGIC INVESTIGATIONS

No records of previous subsurface geologic investigations have been found. As a result, in the past few years state personnel and consultants have visited the site to conduct preliminary geologic studies.

Brief comments on local geology are found in a 1953 U.S. Geological Survey professional paper, "Physiography and Glacial Geology of Western Montana and Adjacent Areas" (Alden 1953). A more comprehensive geologic study of the area is presented in a 1975 University of Montana master's thesis entitled "Geology of the Central Wise River Valley, Pioneer Mountains, Beaverhead County, Montana" (Calbeck 1975).

REGIONAL GEOLOGY

The area surrounding Pattengail Creek lies within the disturbed or thrust belt of the Northern Rocky Mountain Physiographic Province, which is characterized by numerous mountain ranges and intermontane valleys or basins, some at least 15 miles wide.

Bedrock in the northern part of the region is mostly sedimentary units of the Precambrian Belt Series, with some rock of Paleozoic and Mesozoic ages. Belt rocks also occur in the southern part of the region, along with early Precambrian gneiss and schist. In this area, the Precambrian rocks are often overlapped

by folded and faulted Paleozoic and Mesozoic units. Intruded into them are granitic rocks of the Idaho and Boulder batholiths and other outlying intrusives. Tertiary volcanic rocks overlie old, eroded surfaces in many places, particularly in and near Yellowstone National Park. The volcanic rocks range in age from Eocene to upper Miocene or younger. Glacial and other Quaternary deposits lie in most intermontane basins.

SEISMIC ACTIVITY

Southwestern Montana has been intensely disturbed by orogenic processes since at least mid-to-late Cretaceous time. The area is characterized by massive thrust plates, complex thrust zones, innumerable normal faults, and occasional strike-slip faults. Most of the faults strike north or northwest and dip to the west or southwest. A secondary group strikes northeast and dips to the northwest. Attitudes of others are variable.

Most fault movements in Montana died out with the end of Tertiary mountain building, but continuing bedrock adjustments are severe and frequent enough to make Montana one of the most seismically active states in the nation. Since 1925 the state has experienced five seismic shocks that reached intensity VIII or greater (Modified Mercalli Scale). During the same interval, hundreds of less severe tremors were felt. Montana's earthquake activity is concentrated in the mountainous western third of the state, which lies within a seismic zone that also includes southeastern Idaho, western Wyoming, and central Utah.

The Pattengail Creek area is included within Zone 3 of S.T. Algermissen's Seismic Risk Map of the United States (1969), which indicates that it is subject to major damage from earthquakes with an intensity of VIII or higher. (This and the following intensity measures are on the Modified Mercalli Intensity Scale.)

A number of earthquakes of intensity VIII or higher have been recorded in the region surrounding Pattengail Creek. Montana's five strongest recorded earthquakes occurred near Three Forks, Helena, Virginia City, and Hebgen Lake. Three Forks is about 75 miles from the Pattengail Creek dam site and experienced an intensity VIII earthquake on June 27, 1925. Helena, about 80 miles from the dam site, experienced intensity X earthquakes on October 18 and October 31, 1935. Virginia City is about 60 miles from the dam site and experienced an intensity VIII earthquake on November 23, 1947. Hebgen Lake, about 110 miles from the dam site, experienced an intensity X earthquake on August 17, 1959.

SITE GEOLOGY

The Pattengail Creek dam and reservoir would be located in a glacially-modified valley that the creek has carved into Precambrian Age bedrock.

Bedrock beneath the dam site, reservoir floor, and the immediate surrounding area is part of the Missoula Group of the Belt Series. It is mostly fine-grained, light to medium gray or purple-gray quartzite, with occasional zones of light to medium gray metaconglomerate. Severe fracturing is prominent in all outcrops and leads to large deposits of talus at the toes of all steep bedrock slopes. Bedrock in the immediate vicinity of the dam site strikes northwest and dips about 25 to 35 degrees to the southwest (Calbeck 1975).

Five holes were drilled into the subsurface materials beneath the Pattengail Creek dam site. Because of poor core recovery from these drill holes, the interpretations are somewhat less conclusive than desirable, but give a fair idea of subsurface conditions. The locations of the drill holes are shown in figure II-3. Figure A in appendix A shows a detailed geologic cross section of the drill holes.

The bedrock contact was accurately determined only in drill holes DH82-2 and -3. In drill holes DH82-1 and -4, the bedrock surface is interpreted but not confirmed since cores were not recovered. DH82-5 could not be advanced into bedrock because overlying caving conditions could not be cased off.

Judging from the core data that are available, the quartzite underlying the dam varies greatly in competence. In drill hole DH82-2, the bedrock was severely shattered and extremely permeable. In drill hole DH82-3, the small size core (Ax) recovered indicated that the bedrock was quite sound, and percolation tests showed only small water losses. In drill hole DH82-4, no core was recovered; however, percolation tests in the assumed bedrock also showed only small water losses.

Overlying the bedrock at the dam site are Pleistocene and Holocene age deposits of several types. These deposits were formed as a result of alpine glaciation and stream deposition in the valleys of Pattengail Creek and Grouse Creek, one of its tributaries. Of the two glaciers that formed in these drainages, the Pattengail Creek glacier was by far the largest. It originated near Sand Lake and advanced eastward nearly 15 miles to a terminus near the confluence of Sheep Creek and the Wise River. This glacier deposited a series of terminal moraines near the dam site that are almost entirely composed of sand, gravel, cobble, and boulder-sized rock fragments with only minor quantities of silt and clay. Throughout its lower two miles, Pattengail Creek flows over this unconsolidated till, which is mixed with lacustrine (lake) deposits.

The Grouse Creek glacier moved southeastward from the cirque now occupied by Grouse Lakes to the confluence of Grouse and Pattengail creeks. This glacier was smaller than the Pattengail Creek glacier and had a much steeper gradient. Present topography indicates that, after the Pattengail Creek glacier receded, the Grouse Creek glacier continued to dump debris on top of the morainal material deposited by the Pattengail Creek glacier. Thus, Pattengail Creek was forced southward against the valley wall to its present position.

The composite morainal structure formed by these two glaciers dammed the outflow from Pattengail Creek and caused a long narrow lake to form in the lower valley. Fine-grained sediments carried outward from the receding Pattengail Creek glacier were deposited in this lake. These deposits are represented by the silt, fine sand, and silty sand that compose most of the valley floor and the low, remnant terraces lying just above the valley floor. The northern edge of the glacial lake was apparently overridden by the last advances of the Grouse Creek glacier and was shallowly buried by glacial till. Postglacial erosion by the present stream has removed part of the glacial lakebed deposits and produced a wide and slightly lower inner valley. Kame terrace remnants exist high above the valley floor (Calbeck 1975); these would have no effect on the reservoir and were not investigated.

Ground water in the reservoir area comes from local precipitation and the Pattengail Creek tributaries. The low gradient found in ground water levels across the valley, and an apparently close fluctuation between these levels and the creek water level, indicate that the valley fill is quite pervious and allows free movement of ground water both downstream and down gradient laterally.

RESERVOIR GEOLOGY

The reservoir would be founded primarily on lacustrine deposits -- sediments from the lake that once covered the valley. Some areas of its left rim would be composed of morainal till, and areas of the right rim would be composed of quartzite talus.

The lacustrine deposits are fine-grained and consist chiefly of fine sand with some silt. Penetration tests in all except the top part of the material revealed that these deposits have good bearing capacity. Percolation tests indicated that there is very low permeability through the deposits, which appear to have the best water-holding capability of any unconsolidated materials in the area.

Morainal deposits are chiefly sand and gravel with a significant percentage of cobbles and boulders. These deposits have good bearing capacity but are generally quite permeable. Percolation test water losses in this till often exceeded 50 gallons

per minute for a 5-foot-long, 2-inch-diameter uncased drill hole. Fine sand zones do occur within the till, and some silty and clayey zones are present. (The zones represent local pond deposits, or fine-grained outwash near the edges of receding glacial ice.) Leakage through the moraine will occur, although it should be slowed by the long percolation paths through the massive deposit. However, in the area around the dam's left abutment, the percolation distance would be short.

A major problem at the reservoir site is the presence of talus deposits around part of its perimeter. These deposits have developed since the retreat of the last valley glacier and cover deposits laid down by that glacier along the edges of the Pattengail Creek valley. The talus slopes are as high as 400 feet, extremely steep, and may be as much as 50 to 200 feet thick (horizontally) at the base.

The talus deposits grow continuously because rocks roll down from extensively fractured quartzite outcrops on the adjacent mountain sides. Rock-scarred trees and lichen and moss-free boulders show that these rockfalls are recent and continuing.

Past movement of these talus slopes is evident in a hummocky area of talus along the south side of the reservoir. In this area, a large volume of material slid or flowed downslope and laterally outward toward the creek. Bent trees on the talus slopes, caused by slope movement or possibly snowslides, indicate the unstable nature of the slopes. Future slope movements can be expected, especially in areas near the old dam where the natural slope of the talus deposit has been undercut by creek erosion and construction excavations. In addition, the talus is extremely permeable and would have to be removed if it is encountered in the right abutment of the dam.

Seismic activity in this high risk zone could aggravate the situation by causing movement within the talus slopes, liquefaction in the softer lake sediments, and/or extensive rockfalls from the cliffs along the reservoir edges. If a sudden slide occurs either onto the right side of the dam or into a filled reservoir, the dam could be directly damaged by the slide itself or overtopped by a wave of water.

GEOLOGIC CONSIDERATIONS FOR DESIGN AND CONSTRUCTION

Before a dam is constructed at the Pattengail Creek site, several problems must be resolved.

Perhaps the greatest problem is the nature of the foundation materials at the dam site. The left abutment of the old dam and dike area are composed of very permeable till that overlies shattered bedrock in some areas. The present creek section is underlain by approximately 77 feet of lacustrine sand and silt;

the top 15 feet is permeable, soft, and possibly susceptible to liquefaction. The right abutment was not drilled because of excessive cost. It probably consists of permeable glacial till overlain by even more permeable and unstable talus.

To prevent leakage, a positive cutoff beneath the dam and dike may be necessary because of excessive water losses recorded in percolation tests. Based on the expected depth to bedrock in the right abutment area and the permeability of bedrock in the area of the second drill hole (DH82-2 in figure II-3), the cutoff would be difficult to build, as well as expensive.

In the right abutment area, extensively fractured quartzite pinnacles are shedding fresh boulders onto the talus slopes. Also, there is an active snowslide area that aligns with the dam site above the right abutment. Rocks and snow falling from above could pose problems.

Another major problem is the apparent lack of suitable impermeable earth material for constructing the cores of an earthfill dam and dike.

The original dam and dike were built with material from five borrow sites (see figure II-3). The upper site (F) contains fine sand with occasional zones of nearly pure silt. The two lower borrow sites (B, C) are sandy gravel with large amounts of cobbles and boulders, but almost no fines.

At least a portion of the material used in constructing the original dike was borrowed from two shallow pits (D, E) immediately upstream and downstream from the left end of the dike near drill hole DH82-5. The material there is permeable, clean fine sand and silty sand.

None of the original borrow areas contain enough impermeable material to fill a new dam, and the old dam and dike are not built of materials acceptable for modern earthfill core construction.

Lakebed deposits upstream from the old dam also are fine-textured, but consist almost entirely of fine sand with only small amounts of silt. In most instances, they also are too wet and organic to be used as construction material.

Alternatives to an earthfill dam and dike could be structures built with a subsurface slurry trench cutoff, a concrete cutoff wall in the dam, and a main structure mass built from pit run glacial till material or rockfill. The required construction materials are available or could be processed near the dam site.

If any type of dam were built, the old dam and dike are too permeable to be used as a base. The dam apparently is built on a foundation of soft organic material that was not stripped prior to construction. The old structures could either be removed, or

new structures could be constructed along slightly different alignments.

An important factor to consider is the height of a new dam and dike. The top of the old dam was about 40 feet higher than creek level. Apparently it was constructed to intersect the top of the till deposit that is assumed to lie beneath the right abutment talus. However, this design did not prove workable. The literature reviewed indicates that both abutment areas have leaked badly for some time (Perry 1934).

Construction of a new dam and dike at approximately the same height as the old structure would create fewer problems. Even in this case, removing part of the unstable talus slope would be necessary to make the structures safe. The removal of the pinnacles that now serve as a rockfall source above the right abutment would also ensure dam safety. Location of the outlet structures on the new dam toward the left side of the section would avoid talus movement or rockfall that could interfere with their operation.

MATERIALS SUMMARY

Several kinds of materials are necessary for use in the construction of a dam at the Pattengail Creek site. Potential sources of these materials were investigated in the study area.

Impervious

In 1982 an impervious borrow source (Borrow Area A in figure II-3) was investigated with eight backhoe test pits. The area, located about a mile downstream from the dam site and just north of the access trail from the Wise River road, is heavily timbered, primarily with small lodgepole pine.

The subsurface material at the borrow site varies from clean sand and gravel to clean sand and silty or clayey sand. In general, a few feet of fine-textured material overlies either clean sand and gravel or a cobble and boulder bed. Tree roots extend well into the upper portion of the deposit; to remove them, stripping about 1 1/2 feet of surface material would be necessary. Before the area could be used, timber would have to be cut. Nevertheless, the borrow area is small and capable of supplying only about 15,000 cubic yards of brittle, impervious material. Therefore, this source is not suitable for use.

Another possible source of fine-textured material, first identified by Soil Conservation Service personnel, lies about 1 1/2 miles upstream from the Pattengail Creek dam site. This source also was considered for investigation. However, because the contractor's backhoe could not reach this area, exploration plans were abandoned. A close surface inspection of the site

revealed that it contained only a small amount of fine silty sand, and this was within a wet, heavily timbered area. No further subsurface investigations were conducted.

Other possible sources of impervious material are: the silt and fine silty sand terraces upstream; an area near the creek downstream from the dam; and the lakebed deposits upstream from and underlying the dam (see figure II-3). All of these sites contain materials that appear either too limited in quantity, too wet, or too organic to be used as impervious fill.

In conclusion, no source of material suitable for the impervious core construction of an earthfill dam or dike could be found in acceptable quantities within an economic hauling distance of the Pattengail Creek dam site.

Pervious

Pervious material can be processed from the sandy gravel and rock fragments in the moraine deposits of the left abutment. Few fines are present in this material; thus, washing may not be necessary. However, crushing large numbers of cobbles and boulders may be necessary. A crushing operation also could produce pervious material from the quartzite talus on the right abutment.

Other possible sources of pervious material, at longer hauling distances, are gravel deposits along the Wise and Big Hole rivers.

Concrete Aggregate

Concrete aggregate may be processed from the moraine deposits on the left abutment of the dam site or from crushing quartzite talus on the right abutment. Other possible sources along the Wise and Big Hole rivers have not been investigated; the aggregate from them would have to be hauled several miles. Any source of aggregate would have to be tested before it is used.

Riprap and Rockfill

The talus slopes on the right abutment of the dam site could serve as a source of riprap and rockfill. The rock is hard, angular, durable, and large enough for this use. At present, the slopes are unstable. Selective removal of material for construction purposes could reduce their instability.

ADDITIONAL INVESTIGATIONS

Additional subsurface investigations of the right abutment area of the old dam would include drilling at least two holes into underlying bedrock along the proposed dam alignment to determine the talus-till and bedrock contacts. A cross-sectional profile could then be made of the right abutment in order to complete the dam and dike cross section drawn from 1982 investigations (see figure A in appendix A).

Access to the drill sites would be extremely difficult and might require the construction of a drill road across Pattengail Creek and 40 feet up its nearly vertical south bank to the base of the talus slope. From there a skid rig could be winched to drill sites leveled into the talus slope by hand.

Drilling would also be extremely difficult and expensive. No circulation could be maintained in the talus and no core could be recovered from the loose rock. If till does underlie the talus, it is probably quite permeable and susceptible to caving; casing would have to be driven to bedrock. The bedrock may also shatter and cause drilling problems because of permeability and core barrel blockage.

In addition to these subsurface investigations, a detailed seismic evaluation of existing site conditions would emphasize the liquefaction potential of the lake sediments underlying the dam site and the effects of an earthquake on the talus slope of the right abutment.

Chapter III

ENGINEERING ANALYSIS OF THE PATTENGAIL SITE

The structures required to safely store water at the Pattengail dam site are dictated by the physical and geologic conditions of the site. As the information on these conditions has developed, a series of designs and associated costs has evolved.

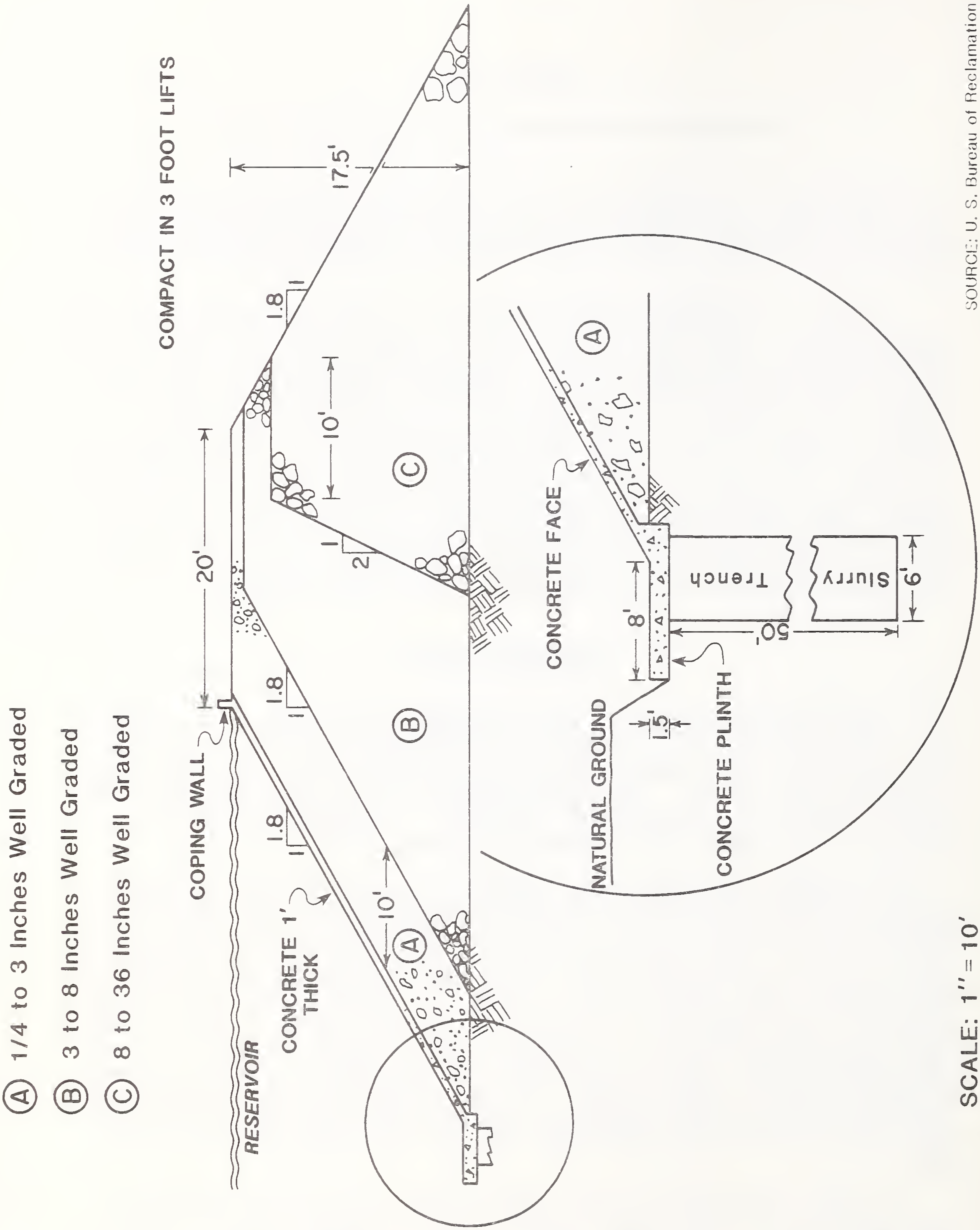
In 1981 an engineering consultant for the Department of Natural Resources and Conservation (DNRC) envisioned an earthfill dam at Pattengail Creek that would cost an estimated $4.2 million in July 1982 dollars (DNRC 1981). However, subsequent investigations, as discussed in Chapter II, have indicated that the earthfill structure is not feasible. Earthfill dams require large amounts of fill which must meet a narrow range of specifications. No source of enough impervious materials meeting these requirements exists near the dam site. Also, investigations showed that the foundation conditions at the site are more complex than assumed from preliminary analyses. With this information, a new dam design has been developed; this design would cost approximately $14.4 million in July 1982 dollars.

PROPOSED DESIGN

The updated design for the Pattengail dam site is a rockfill dam with a slurry trench cutoff, an ungated concrete chute service spillway, a grass-lined auxiliary spillway, and a concrete conduit-type outlet. The upstream face of the dam would be concrete, forming an impermeable barrier. A layout of the dam structures is shown in figures III-1 and III-2.

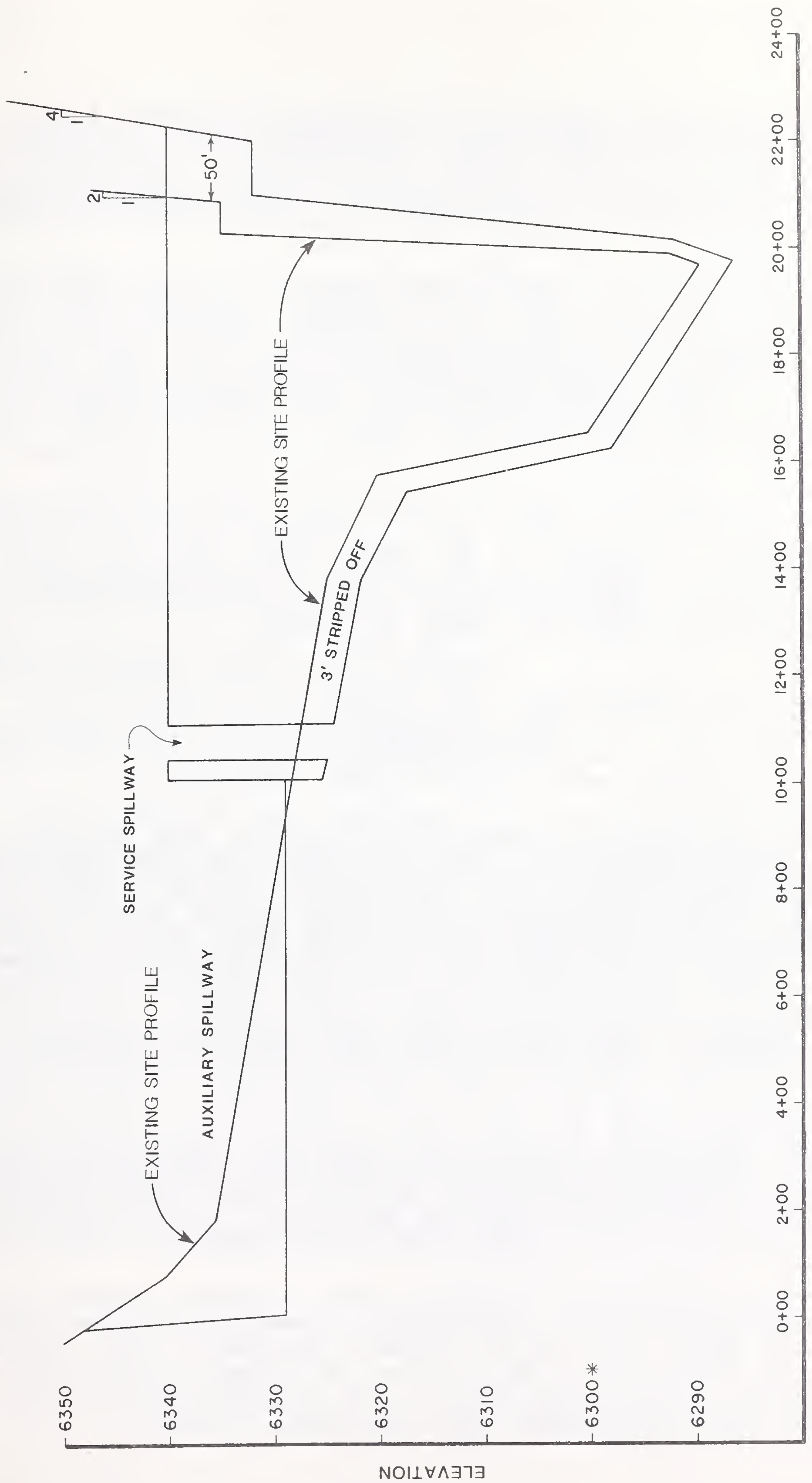
To prepare the site, the remnants of the old dam and approximately 3 feet of undisturbed ground would have to be removed. Using the alignment of the old dam would require the least amount of new fill. This would also be the best location for tying into the talus on the right slope. The talus slope on the right abutment of the old dam structure would be excavated 50 feet horizontally and laid back to a slope of 4:1 (see figure III-2). Since the actual thickness of the talus on the right abutment has not been determined, for the purposes of preliminary design, it was assumed to be 50 feet thick. If the assumed talus thickness is correct, 119,000 cubic yards of talus would have to be removed. Most of this material would be used in the construction of the dam.

The dam embankment would rise 48 feet above the streambed, and would have a top width of 20 feet and slopes of 1.8:1 upstream and downstream. Approximately 93,000 cubic yards of rock processed from the materials removed from the talus slope would be used in building the dam.



SOURCE: U. S. Bureau of Reclamation

FIGURE III-1 PATTENGAIL CREEK ROCKFILL DAM: TYPICAL CROSS SECTION



SOURCE: U. S. Bureau of Reclamation

FIGURE III-2 DAM PROFILE

The rockfill would be placed in three zones (see figure III-1). Zone A would consist of 11,500 cubic yards of 1/4- to 3-inch well-graded gravel. Zone B would contain 32,000 cubic yards of 3- to 8-inch well-graded rock. Zone C would consist of 49,000 cubic yards of 8- to 36-inch (pit run) well-graded rock. The rockfill would be compacted in 3-foot lifts.

A bentonite slurry cutoff trench would be placed under the upstream toe of the dam to minimize seepage under the dam. This trench would average 50 feet deep and about 6 feet wide, although the actual width of the trench would be dictated by the size of rocks found in the cutoff excavation. Approximately 4,000 cubic yards of bentonite would be required. It may be necessary to introduce barite into the bentonite slurry to increase slurry density.

No core drilling was done in the right abutment to determine the talus depth. If talus in this area exists below the level observed on the exposed cut bank, an alternate type of cutoff would be required. However, costs would not be significantly affected if another type of cutoff is needed.

As noted in Chapter II, the only impermeable material found in the area was a relatively small amount of a brittle silt. This type of silt is somewhat less than ideal for use as an impermeable dam core. Covering the upstream face of the dam with 1-foot-thick concrete would make the dam impermeable.

Since the dam site is located in an area of high seismic risk, the dam's concrete face must be capable of some deformation during an earthquake while still maintaining the integrity of the structure. To allow for this, the concrete would be poured in small sections tied together with flexible water stops. At the top end of the concrete face, a 1-foot-high concrete coping wall would be placed to turn high waves. On the upstream toe of the dam, the concrete face would be tied to the slurry trench with a concrete plinth 1.5 feet thick and 8 feet long. The concrete face, coping wall, and plinth would require 3,300 cubic yards of concrete.

The dam would have a total flood discharge capacity of approximately 30,200 cubic feet per second (cfs), which would be suf- ficient to pass the probable maximum flood. Three structures would provide this discharge capacity: the main spillway, the auxiliary spillway, and the controlled outlet.

Foundation conditions at the site do not favor the use of a concrete overflow section. Therefore, a concrete ungated chute spillway was chosen for use as the main spillway. This spillway would have a semi-circular drop inlet, an ungated chute, and a stilling basin terminal structure. The spillway could handle 10,000 cfs, which is greater than the 100-year flood.

The auxiliary spillway for the structure would be grass-lined with a concrete scour pad at the crest and a 3-foot-high fuse plug. The fuse plug would be constructed with an impermeable material on the upstream face backed by a permeable material, which would wash out quickly when the fuse plug is overtopped.

The Bureau of Reclamation hesitates to recommend the use of fuse plugs; however, they might be feasible at the site due to the amount of freeboard available. Considering winter weather conditions at the site, it is possible that a fuse plug might freeze in position when it should collapse. The use of a fuse plug would be analyzed further during final design.

The auxiliary spillway would be 1,000 feet wide and would have a maximum water depth of 4 feet at the crest. The maximum capacity of the auxiliary spillway would be 20,000 cfs.

The controlled outlet would be a 200-foot-long concrete conduit with a capacity of 200 cfs. Specifically, the controlled outlet would consist of a box inlet, two square slide gates, and a stilling basin outlet. The outlet could drain 95 percent of the water behind the dam in 30 days.

PROJECT COSTS

The engineers' cost estimate for the dam on Pattengail Creek evolved from a series of calculations. The itemized costs in the estimate were calculated in October 1981 dollars; the total estimated cost for the structure was then updated to July 1982 dollars, using the latest Bureau of Reclamation construction cost trends as an indexing guide. The total capital cost was estimated at $14.4 million in July 1982 dollars (see table III-1).

Along with the specific structures described here, several miscellaneous items were included in the cost estimate. These items include: blasting 2,000 cubic yards of rock from the pinnacles above the right side of the old dam; diversion of the stream during construction; relocation of three buildings; purchase of 100 acres of land; relocation of 1 mile of unimproved road; and the clearing of 200 acres of forested land. The buildings, private lands, and most of the forested lands are in areas below the spillways of the dam.

Table III-1. Engineers' Cost Estimate of the Pattengail Dam Facility

Description	Quantity	Unit[1]	Unit Price	Amount
Dam structure				
Remove old dam	48,000	cy	$ 2.00	$ 96,000
Surface stripping	14,000	cy	3.00	42,000
Slurry trench	125,000	cy	6.00	750,000
Zone A: crushed gravel	11,500	cy	10.00	115,000
Zone B: crushed rock	32,000	cy	7.00	224,000
Zone C: pit run rock	49,000	cy	6.00	294,000
Rock removal/blast pinnacle	2,000	cy	10.00	20,000
Excavate and waste talus slope	26,000	cy	1.00	26,000
Concrete -- dam face	3,300	cy	130.00	429,000
Reinforcing steel	260,000	lbs.	.80	208,000
Cement	18,000	cwt	6.00	108,000
Waterstop - A	23,000	ln.ft.	6.00	138,000
Auxiliary spillway				
Excavation	440,000	cy	$ 4.00	$1,760,000
Impermeable fill-fuse plug	670	cy	3.50	2,300
Permeable fill-fuse plug	1,300	cy	3.50	4,550
Concrete -- sidewall	610	cy	2.00	122,000
Reinforcing steel	49,000	lbs.	.80	39,200
Cement	3,300	cwt	6.00	19,800
Concrete (scour pad)	1,500	cy	130.00	195,000
Reinforcing steel	120,000	lbs.	.80	96,000
Cement	8,100	cwt	6.00	48,600
Surface clearing	200	acres	750.00	150,000
Miscellaneous items				462,550
Contingencies (25%)				1,350,000
	Field Cost Total			$6,700,000
Service spillway		Job		2,900,000
Outlet		Job		300,000
Stream diversion during construction		Job		490,000
Relocations & land acquisitions				245,000
Indirect costs[2]				3,165,000
Project Cost (Oct. 1981 dollars)				$13,800,000
Project Cost (July 1982 dollars)				$14,400,000

[1] cy = cubic yards; cwt = hundred weight; ln. ft. = linear feet.

[2] Indirect costs include additional feasibility analyses, archeological and environmental investigations, engineering design, project administration, etc.

In addition to capital costs, annual operating costs must be considered. Table III-2 shows an estimate of the annual costs associated with operation of the dam. These costs were estimated by using Bureau of Reclamation cost curves that are based on a large number of dams of a size similar to the Pattengail facility.

Table III-2. Annual Costs of Pattengail Facility (in July 1982 dollars).

ACTION	COST/YEAR
Operation	$ 9,869
Maintenance	6,579
Administrative and general expenses	4,112
Replacement	411
TOTAL	$20,971

Source: U.S. Bureau of Reclamation.

Chapter IV

ECONOMIC ANALYSIS OF THE PATTENGAIL SITE

DESCRIPTION OF THE STUDY AREA

The total natural flow of the Big Hole River averages 1,132,372 acre-feet of water per year. Although this is greater than the total annual demand for Big Hole River water (1,115,000 acre-feet), a water shortage exists in August and September in one out of every three years. The total demand is based on consumptive and minimum instream flow requirements for the basin. The annual flow distribution in the Big Hole River is shown in figure IV-1.

In some years, the water shortage on the Big Hole River has reduced instream flows to the point of reducing carry-over fish populations and interrupting irrigation (Kozakiewicz 1979, Wells and Decker-Hess 1981). The reservoir on Pattengail Creek could store water for release during these critical periods, thereby alleviating the problems resulting from inadequate stream flow.

The results of an economic prefeasibility study of the dam on Pattengail Creek, including the project's costs and benefits to irrigated agriculture and recreation, are presented here. For the purposes of the economic analysis, the study area extends from the dam site on Pattengail Creek, along the Wise and Big Hole rivers to the confluence of the Big Hole River with the Jefferson River at Twin Bridges (see figure IV-2). The analysis of recreation focused on the portion of the study area that encompasses Pattengail Creek, the Wise River, the Big Hole River, and the moose habitat behind the dam in the Pattengail drainage. The analysis of agriculture focused on the lower Big Hole River Basin, extending from the Melrose gauging station (7 miles downstream from Melrose) to the river's confluence with the Jefferson River at Twin Bridges.

Much of the information on recreation in the Big Hole River Basin used in this study is from the Montana Department of Fish, Wildlife and Parks (DFWP). For management purposes, DFWP divides the river into three reaches. In the discussion of Pattengail project's recreational costs and benefits, references will be made to reaches 1 and 2. Reach 1, as shown in figure IV-2, extends from the old Divide Dam to the mouth of the Big Hole River at Twin Bridges. Reach 2 extends from Pintlar Creek to the old Divide Dam. Reach 3, from the uppermost portion of the basin to the old Divide Dam, was not included in the study area.

The portion of the river studied currently supports the recreational activities of about 50,000 fishermen and boaters each year and annually provides irrigation water for 21,769 acres of land. In this study, incremental increases in instream flows were evaluated to determine the additional recreational and agricultural benefits and costs of the dam on Pattengail Creek.

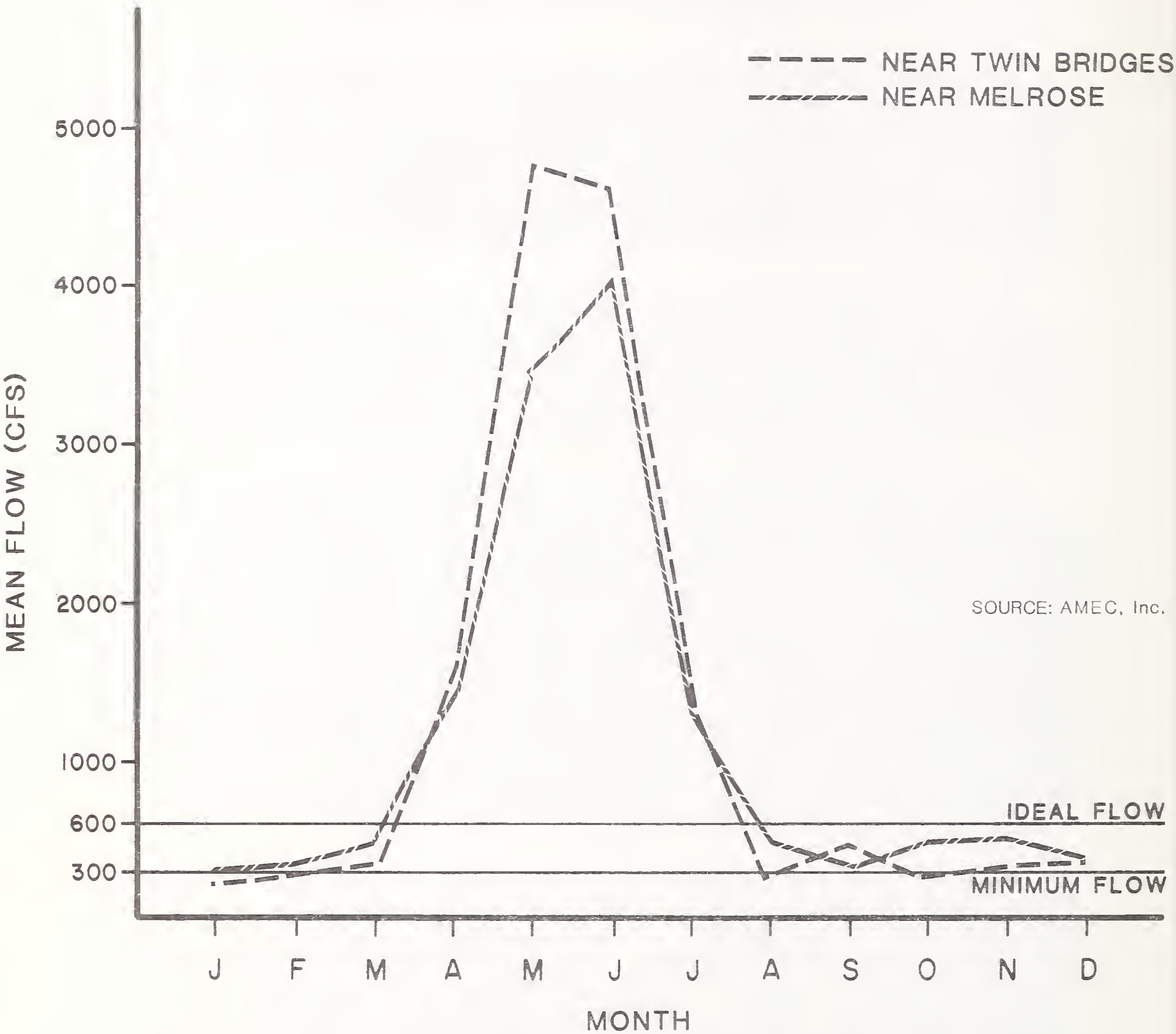


FIGURE IV-1 MEAN MONTHLY FLOWS OF THE BIG HOLE RIVER NEAR MELROSE AND TWIN BRIDGES

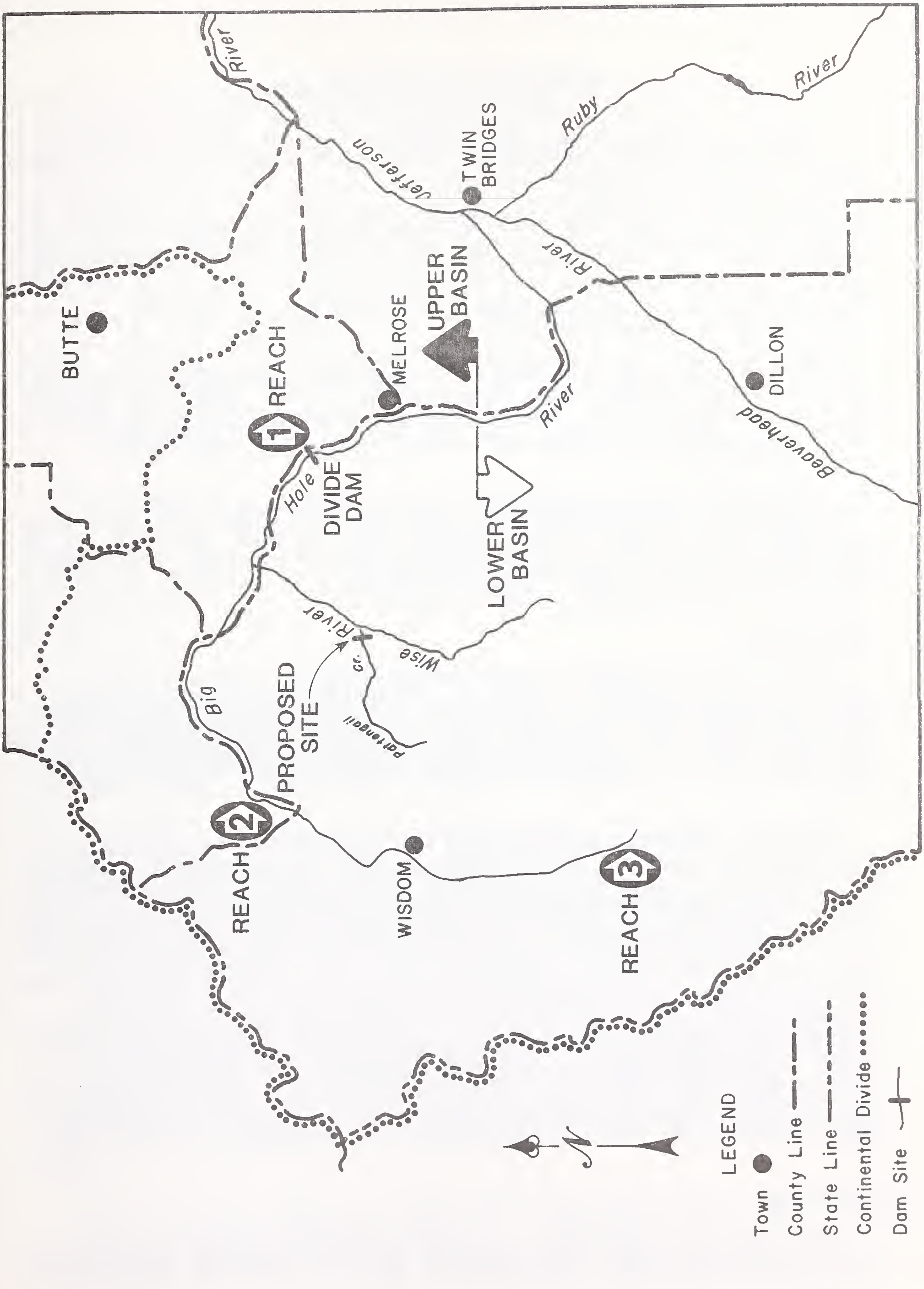


FIGURE IV-2 STUDY AREA FOR ECONOMIC ANALYSIS

PROCEDURES AND DATA SOURCES

Separate methods were used to evaluate the benefits and costs of agriculture and recreation.

A partial budgeting approach, in which the added benefits and costs were evaluated on all currently irrigated land in the lower basin (21,769 acres), was used to analyze the agricultural component. In this analysis, the farmers' ability to pay for increased irrigation, as well as their "willingness to pay" for increased irrigation, were examined.

In analyzing the recreational component, secondary data were used to estimate the value of recreation -- that is, the number of recreationists who use Big Hole River water and their "willingness to pay" for this use (Wells and Decker-Hess 1981, Sutherland 1982).

The major costs considered in the cost-benefit analysis were for constructing, maintaining, and operating the dam, and for mitigating the effects of dam construction on upstream moose habitat. Dam-related costs were provided by the Bureau of Reclamation in its engineering report (BR 1982).

Agriculture

The "ability and willingness" of farmers to pay for supplemental irrigation water from the Pattengail project were determined through a partial budgeting approach. This approach simply estimates the added benefits (added returns and reduced costs) and added costs (reduced returns and added costs) of a proposed action.

Several sources of data were used to assess the agricultural costs and benefits of the Pattengail dam. To establish a baseline budget, a study of the enterprise cost of crop production in the area was used (Schaefer, Griffith, and Luft 1978). This budget was updated according to agricultural price indices published by the U.S. Department of Agriculture (USDA 1978, USDA 1982). The crop budgets used to describe the current water use situation in the Big Hole River Basin and the "after dam construction" scenarios also are from the USDA agricultural price indices and the Montana Cooperative Extension Service (O'Connell and Luft 1981). The Department of Natural Resources and Conservation (DNRC) study of water use on the Big Hole River provided data on the farmer's "willingness to pay" for the augmented irrigation water supplies from tributary storage on Pattengail Creek (DNRC 1981).

Recreation

The Big Hole River Basin is one of Montana's most popular recreation areas; the area receives 66,000 fisherman days of use

in a typical year (DNRC 1981). Along with fishing, other recreational opportunities include canoeing, rafting, camping, picnicking, birdwatching, hunting, sightseeing, etc. For the purposes of this analysis, instream recreation (fishing and boating) and moose hunting were used as economic factors. If the Pattengail project were constructed, its effect on other types of recreation would have to be considered. The recreation benefits provided by the Pattengail project itself also should be considered.

Three common methods of evaluating the economics of outdoor recreation are contingent valuation, travel cost, and unit day value. The contingent valuation method, as used in this study, obtains estimates of the benefits derived from a particular action by asking recreationists about their "willingness to pay" for the proposed change. Use of this method maintained uniformity between the agricultural and recreational assessments.

Lack of existing data on recreation in the Big Hole River Basin and the study's time frame required the use of information from a similar study of the Flathead River system (Sutherland 1982). Although the Flathead River is several hundred miles from the Big Hole River, similarities between the two rivers allowed Flathead River data to be applied to this study of the Big Hole River.

In this study, a recreationist is defined as either a fisherman, boater, or moose hunter. Data on fisherman days were from DFWP creel census information (1975 to 1976) updated to 1982 by assuming an annual increase of 3.25 percent, the rate at which Montana fishing license sales have increased since that time (Workman 1982).

Although fisherman day information is accessible, other recreation day (i.e., boating) information is not as available. Therefore, this study assumed that the relationship of boater to fisherman was much the same as on the upper Madison River. Based on studies conducted there (North Texas State University 1981), this analysis assumed a ratio of one recreational boater for every 25 fishermen.

Since the months of August and September represent the critical time frame for this study, the data on fishing and boating were broken down by month, using a study of the lower Big Hole River trout fishery (Kozakiewicz 1979). Since only portions of Pattengail Creek, the Wise River, and the Big Hole River are in the study area, the number of fishing days then was adjusted by the percentage of the creek's or river's total area in the study area.

The study was concerned only with the additional net benefits of the developed Pattengail project. Therefore, it was necessary to devise a method to determine the number of fishermen at various levels of instream flow. Following an approach used by

DFWP, the number of fishermen -- and, thus, the number of boaters -- was assumed to vary directly with the number of brown trout. The resultant regression equation correlated levels of instream flow, measured in cubic feet per second, with populations of brown trout age four or older (Wells and Decker-Hess 1981). With this equation, the number of brown trout (age IV+) were the proxy for the number of fishermen and boaters.

There is little data on moose hunting or moose populations and carrying capacity in the Pattengail Creek area. Although the drainage is an important winter range for moose, it represents only a small portion of the total available winter range (DFWP 1982). Some of this range would be affected by the dam.

At present, five moose permits are issued for the hunting district that includes the Pattengail drainage (DFWP Hunting District 324). According to DFWP's most recent hunting data (1975 to 1981), no moose were harvested in the Pattengail drainage during that period. However, a conservative estimate of the costs of lost moose habitat was made, using moose hunting expenditures as an estimate for willingness to pay (State of Wyoming 1980) and the assumption that the five moose permittees would be affected by the loss of moose habitat at Pattengail Creek if the project were constructed.

Dam Costs

The most significant cost items in this study are the construction, operation, maintenance, and replacement costs of the Pattengail water storage facility. Construction costs are $14,400,000 according to the Bureau of Reclamation's most recent estimates (BR 1982). For the economic analysis, it was assumed that the life of the project is 100 years, with an annual interest rate of 7 5/8 percent.

NOTE: For additional information on the data and procedures used in the economic analysis, see appendix B.

RESULTS AND DISCUSSION

Water Demands

The primary demands for water in the lower Big Hole Basin are for agriculture and recreation uses. The demand for municipal uses is minor by comparison and was assumed to remain at the present level (26,668 acre-feet per year).

In the lower Big Hole River Basin, about 21,769 acres now are irrigated. Most of this land is along the river between Melrose and the river's mouth near Twin Bridges. The primary crop is flood irrigated alfalfa-grass hay, which requires a diversion of 5.34 acre-feet of water per acre (DNRC 1981). Based on this

diversion requirement, the total irrigation demand for this portion of the basin is 116,162 acre-feet per year. Although a significant portion of the diverted flow eventually will be returned to the river, the return flow has not been considered in the demand calculation because much of this water will return to the river via the ground water system -- a process that can take several months.

Reach 1 of the Big Hole River, from the Divide Dam to the river's mouth, is classified as a blue-ribbon fishery. In order to sustain a maintenance-level fish habitat on this lower reach, 522,265 acre-feet per year of instream flow are needed (DNRC 1981). Table IV-1 shows the average monthly water supplies, demands, and shortages associated with a maintenance-level fish habitat in the lower Big Hole River Basin.

Table IV-1. Average monthly water supplies, demands, and shortages for maintenance-level of fish habitat in the lower Big Hole River Basin.

Month	Water Supplied	Irrigate Demands	Maintenance Level Instream Demands	Total Demands	Balance	Balance (cfs)[1]
	acre-feet					
Jan	21,031	0	18,442	18,442	2,589	42
Feb	19,641	0	16,657	16,657	2,984	54
Mar	27,424	0	18,442	18,442	8,982	146
Apr	92,381	0	41,854	41,854	50,527	849
May	223,372	26,727	134,896	161,623	61,749	1,004
Jun	267,153	18,625	160,442	179,067	88,086	1,480
Jul	93,829	35,375	40,512	75,887	17,942	292
Aug	34,383	28,723	18,442	47,165	-12,782	-208
Sep	23,377	6,712	17,847	24,559	- 1,182	- 20
Oct	32,659	0	18,442	18,442	14,217	231
Nov	30,681	0	17,847	17,847	12,834	216
Dec	23,777	0	18,442	18,442	5,335	87
TOTALS	889,708	116,162	522,265	638,427	251,281	

[1] cfs = cubic feet per second

Source: DNRC (1981), p. 17; and DNRC (1981a), p. 77.

With a total supply of water to the lower basin of 889,708 acre-feet per year, on an annual basis, all water demands appear to be easily met. However, the timing of these flows each year creates a water shortage problem in certain months.

The dam on Pattengail Creek would alleviate most of the dewatering problems on the Wise and the Big Hole rivers. The reservoir's yield would add up to 10,140 acre-feet (170 cfs for 30 days) to the instream flows. In an average year, this would be enough to eliminate 73 percent of the shortages for currently irrigated lands and would provide a maintenance-level habitat for the fishery in the Wise River and the lower Big Hole River. In a dry year (the driest year in ten), stored water from Pattengail could alleviate 26 percent of the total shortage (DNRC 1981).

Benefits

Agriculture Benefits

With a tributary storage facility on Pattengail Creek, the Big Hole River Basin farmer would have a more dependable supply of irrigation water. If the dam were built, the irrigator could expect a full supply of water in nine years out of 10 on 73 percent of the lands presently irrigated.

The irrigator would have to purchase this supplemental water. Since the water would likely be expensive, this analysis assumed that the irrigator would take certain actions to maximize production and justify the expense. The specific assumptions used in this study are that:

1. Fifty percent of the land area will remain under flood irrigation systems. Higher yields will be achieved on these lands by increasing water and fertilizer application rates.

2. Fifty percent of the land area will be under side roll sprinkler irrigation systems. Better yields on these lands will be achieved with higher fertilizer application rates.

3. On land receiving only additional fertilizer, average hay yields will increase from 2.2 to 2.8 tons per acre. On lands under sprinkler irrigation and receiving additional fertilizer, hay yields will increase from 2.2 to 4.0 tons per acre. A price of $60 per ton is assumed for alfalfa-grass hay.

Three crop enterprise budgets, representing the current situation and flood and sprinkler irrigation once the Pattengail dam project is constructed, are summarized in table IV-2. The individual crop enterprise budgets and a list of the specific assumptions for each budget are presented in appendix B.

Table IV-2. Per acre costs and returns of producing irrigated alfalfa-grass hay under the current situation and with flood and sprinkler irrigation after project completion.

Description	Current Situation Flood	After Project Flood	Sprinkler	Total Project[2]
Gross returns from production				
Alfalfa-grass hay[1]	$132.00	$168.00	$240.00	$204.00
Total gross returns	132.00	168.00	240.00	204.00
Variable costs				
Nitrogen	8.00	8.00	8.00	8.00
Phosphate	8.00	12.00	12.00	12.00
Irrigation labor	9.95	9.95	2.83	6.39
Machinery: fuel, oil, repairs	17.88	21.46	26.83	24.15
Pickup v.c.	6.00	6.00	6.00	6.00
Miscellaneous expense	8.14	9.77	12.21	10.99
Machinery labor	6.72	8.06	10.07	9.07
Irrigation maint. and elec.	0.00	0.00	20.75	10.38
Management	9.24	11.76	16.80	14.28
Interest on operating capital	2.00	2.44	3.04	2.74
Total variable costs	$ 75.93	$ 89.44	$118.53	$103.99
Return over variable costs	$ 56.07	$ 78.56	$121.47	$100.02
Breakeven price, based on variable costs	$ 35.51	$ 31.94	$ 29.63	$ 30.58
Breakeven yield, based on variable costs (tons)	$ 1.27	$ 1.49	$ 1.98	$ 1.73
Fixed Costs:				
Irrigation water	$ 5.00	$ 5.00	$ 5.00	$ 5.00
Machinery & tractors	34.13	34.13	34.13	34.13
Taxes (land & improvements)	4.49	4.49	4.49	4.49
Interest, insurance & depreciation (land & improvements)	47.40	47.40	47.40	47.40
Irrigation (dep., int., & ins.)	0.00	0.00	46.66	23.33
Prorated establishment costs	9.98	9.98	9.98	9.98
Total fixed costs	$101.00	$101.00	$147.66	$124.33
Total costs	$176.93	$190.44	$266.19	$228.32
Net returns	-44.93	-22.44	-26.19	-24.32
Breakeven price, based on total costs	$ 80.42	$ 68.01	$ 66.55	$ 67.15
Breakeven yield, based on total costs	$ 2.95	$ 3.17	$ 4.44	$ 3.81
Net return difference from current situation	n/a	$ 22.49	$ 18.74	$ 20.62

1 The baseline flood, project flood, and project sprinkler cases assume hay yields of 2.2, 2.8, and 4.0 tons per acre, respectively. An average hay price of $60 per ton is used.

2 The total project column assumes that half of the farmers will increase only their fertilization rates and half will increase their fertilization rates and improve their irrigation systems.

The current situation is representative of the lower basin at the time of the study -- that is, the land was assumed to be producing alfalfa-grass hay (2.2 tons per acre) under a flood irrigation system. The other two budgets, flood irrigation and sprinkler irrigation after the project is constructed, are representative of the changes in crop production in the lower basin. The flood irrigation budget (with the dam project) assumed that the phosphate fertilizer application rate increased from 40 to 60 pounds per acre and the hay yield increased from 2.2 to 2.8 tons per acre. The sprinkler irrigation budget (with the dam project) assumed the same phosphate fertilizer increase as above, the introduction of a side roll sprinkler irrigation system, and a yield increase from 2.2 to 4.0 tons per acre. Assuming a 7 percent return to management, the net return was negative in all cases. (An examination of any irrigated-crop budget for the state of Montana would reflect similar economic losses.)

Based on the information and assumptions used in this study, the average farmer would realize an annual reduction in his/her current losses of $20.62 per acre. Table IV-3 summarizes the net benefits to flood and sprinkler irrigated hay with the Pattengail dam project. It is assumed that half of the acres would be flood irrigated and the other half sprinkler irrigated.

Table IV-3. Net benefits to irrigated agriculture with the completion of the project.

Item	Difference from Current Situation	Number of Acres	Total Net Benefits
	($/acre)		
Flood irrigation	22.49	10,884.5	$244,792
Sprinkler irrigation	18.74	10,884.5	203,976
TOTAL	20.62	21,769.0	$448,768

The Pattengail dam project would provide $448,768 ($44.26 per acre-foot) in benefits if all the water from its reservoir (10,140 acre-feet) were allocated to agriculture. Table IV-4 summarizes the total net benefits to agriculture, using a range of yields and prices for flood and sprinkler irrigated lands.

Table IV-4. Total net benefits to agriculture assuming various yields and prices for alfalfa[1]

Price ($/ton)	Yield (tons/acre) 3.0	3.4	3.8
50	$-330,834	$124,682	$ 529,585
60	-118,260	448,768	914,244
70	94,314	732,037	1,298,902

[1] These yields are average yields, assuming total reservoir storage is dedicated to agriculture and is evenly split between sprinkler and flood irrigation.

Recreation Benefits

The water shortages in the lower Big Hole River directly affect instream activities; the shortages are harmful to fish habitat and do not leave enough instream flow for boating on the river.

In this analysis, the primary instream activities -- fishing and boating -- were evaluated according to fisherman and boating days along the different reaches of the river. Onshore activities, such as camping and picnicking, were assumed to remain unchanged with changes in the instream flow (Daubert and Young 1981).

Table IV-5 summarizes fisherman day information.

Table IV-5. Total fisherman days included in the study area.

Creek/River	Total Fishing Days	Percent in Study Area	Total Fishing Days
Pattengail Creek	626	10%	63
Wise River	4,050	40%	1,620
Big Hole River			
Reach 1	40,926	100%	40,926
Reach 2	24,009	30%	7,203
TOTAL			49,812

Source: Mail creek census data collected by Montana Department of Fish, Wildlife and Parks, 1975-1976.

Table IV-6 summarizes the fishing and boating day estimates for each creek or river in the study area by month.

Table IV-6. Average fishing and boating activity in the study area for each month (in days).

	Use per month	Pattengail Creek Fishing	Wise River Fishing	Big Hole River Reach 1 Fishing	Big Hole River Reach 1 Boating	Big Hole River Reach 2 Fishing	Big Hole River Reach 2 Boating	Total Fishing	Total Boating	Total
Jan	0	0	0	0	0	0	0	0	0	0
Feb	0	0	0	0	0	0	0	0	0	0
Mar	0	0	0	0	0	0	0	0	0	0
Apr	0	0	0	0	0	0	0	0	0	0
May	9	6	146	3,683	147	648	26	4,483	173	4,656
Jun	26	16	421	10,641	426	1,873	75	12,951	501	13,452
Jul	23	14	373	9,413	377	1,657	66	11,457	443	11,900
Aug	24	15	389	9,822	393	1,729	69	11,955	462	12,417
Sep	10	6	162	4,093	164	720	29	4,981	193	5,174
Oct	4	3	65	1,637	65	288	12	1,993	77	2,070
Nov	4	3	65	1,637	65	288	12	1,993	77	2,070
Dec	0	0	0	0	0	0	0	0	0	0
ANNUAL TOTALS		63	1,621	40,926	1,637	7,203	289	49,813	1,926	51,737

An annual total of 51,737 visitor days, including 49,813 fisherman days and 1,926 boater days, was estimated for the area. Using the fisherman day and boater day values of $5.93 per day and $11.23 per day drawn up by Sutherland (1982), the value of the Big Hole River Basin study area for recreational use is $317,003.

Water stored behind the dam on Pattengail Creek would be used to increase the instream flows on each of the reaches in the study area. In order to estimate the increase in fisherman and boating activity with the increased instream flow, DFWP data were used to generate a correlation between minimum August instream flows and fish populations (Wells and Decker-Hess 1981). As stated previously, the fish populations were assumed to be a proxy for fisherman activity. Also, fish populations and fisherman days were assumed to increase (or decrease) at the same rate. The DFWP information generated the following regression equation:

$$y = 364.73 + .74\,x \quad (R^2 = .8898)$$

where: y = number of fish
x = instream flow, measured in cubic feet per second (cfs)

The average minimum flow is 293.8 cfs. The average number of age IV+ brown trout (proxy for fisherman days) is 582.7 fish. Finally, the average numbers of fisherman days for August and September are 385 and 166, respectively. Therefore, one fish represents .66 and .28 fishermen per day in the months of August and September, respectively. Boating days will increase at the same rate as fisherman days.

Four scenarios were evaluated to assess the project's net benefits to fishing and boating:

1. The dam releases 100 cfs for the month of August and 70 cfs for the month of September. The entire added supply of water is available and added to the instream flows on Pattengail Creek, Wise River, and Reaches 1 and 2 of the Big Hole River.

2. The dam releases 100 cfs for the month of August and 70 cfs for the month of September. While 100 percent of the water is available to the instream flows on Pattengail Creek, Wise River, and Reach 2 of the Big Hole River, only 75 percent of the additional water is available to Reach 1.

3. The same as number two, except that only 50 percent of the additional water is available to Reach 1.

4. The same as number two, except that only 25 percent of the additional water is available to Reach 1.

Table IV-7 summarizes the net benefits for instream uses due to the additional instream flow. The table shows the current situation for August, September, and the other months of the fishing season, and the total additional net benefits of the increased flow.

Table IV-7. Net recreational benefits assuming 25, 50, 75, and 100 percent of the additional flow from the Pattengail dam facility is available for instream use in Reach 1 of the Big Hole River.[1] (cfs = cubic feet per second)

Monthly Release from Patt. (cfs)	Add'l. Water Available Reach 1 (cfs)	Rec. Activity Patt. & Reach 1 (user-days) Fishing	Boating	Add'l. Rec. Activity Reach 1 Fishing	Boating	Add'l. Net . Benefits ($)	Add'l. Net Benefits ($/acre-foot)
Projected	100	269	8	1,238	50	$ 9,582	$0.94
August	75	269	8	926	37	7,593	0.75
Release	50	269	8	614	25	5,603	0.55
(100 cfs)	25	269	8	302	12	3,614	0.36
Projected	70	78	2	360	14	2,785	0.27
September	52.5	78	2	269	11	2,205	0.22
Release	35	78	2	178	7	1,625	0.16
(70 cfs)	17.5	78	2	87	3	1,045	0.10
Projected	0	674	27	3,102	124	24,083	2.38
Release[2]	0	674	27	2,320	93	19,095	1.88
October	0	674	27	1,538	62	14,107	1.37
through July	0	674	27	756	30	9,119	0.90
(0 cfs)							
Yearly	170	1,020	37	4,700	188	36,450	3.59
Total	127.5	1,020	37	3,515	141	28,893	2.85
(170 cfs)	85	1,020	37	2,330	93	21,335	2.60
	42.5	1,020	37	1,146	46	13,728	1.36

[1] For the purposes of this study, only fishing and boating were considered significant recreational benefits. The area between Pattengail and the beginning of Reach 1 has been assumed to receive 100 percent of the release for instream use.

[2] Larger carry-over populations result in additional benefits in months when no releases from Pattengail are planned.

The dam would improve the fish habitat in the Big Hole River and, in turn, increase fish populations for the months of August and September. Maintenance of fish populations during these critical months would improve the fishery for all other months of the year. If the total additional water supply from the project were allocated to instream uses, the project would provide

$36,450, or $3.59 per acre-foot, in recreational benefits in the first year after construction. Assuming that only 75, 50, or 25 percent of the water is available for instream uses, during the first year after construction $28,893, $21,335, and $13,778 of additional benefits, respectively, would be realized.

In the current situation, the Big Hole River's fish carrying capacity is limited because of periodic water shortages. If the water shortages could be reduced or eliminated, the number of fish in the fishery could be increased. It was estimated that the fish population eventually could be doubled from the level attained in the first year following dam construction; this dramatic increase would occur in the period between the second and fifth year after construction (Wells 1982). Assuming that this estimate is reasonable, the additional benefits of the project would be $36,450 in year one, $100,072 in year two, $175,145 in year three, $263,732 in year four, $353,453 in year five, and $353,453 in each year over the lifetime of the project. This would yield estimated additional annual benefits of $345,069, or $34.03 per acre-foot of water supplied.

It is apparent that the project's annual net benefits for recreation are very sensitive to how the fish populations respond to the increased instream flows. If the fish population increases in the first year by 11 to 12 percent and stabilizes at that level, the annual net benefits to fishing and boating would be $36,450. However, if the additional instream flow promotes sustained growth, allowing the fish population to double, annual net benefits to fishing and boating would be $345,069 -- assuming all additional flows provided by the reservoir are allocated to instream use.

Costs

Dam

The construction, operation, and maintenance costs of the dam were estimated by the Bureau of Reclamation and updated to July 1982 dollars. The bureau reported the following costs:

Construction	$14,400,000
(amortized over 100 years at 7 5/8 percent interest)	1,060,240
Operations	9,869
Maintenance	6,579
Administration	4,112
Replacement	411
Total annual costs	$ 1,081,211

The total costs ($1,081,211, or $106.63 per acre-foot of water) are based on the firm average annual yield of the dam (10,140 acre-feet).

Moose Habitat

The hunting area behind the Pattengail dam site (DFWP Hunting District 324) is an important winter range for moose (Peterson 1982), although the Pattengail Creek drainage represents only a small portion of the entire district. Five moose permits are issued each year for the hunting district. Considering the highest use scenarios, and using information on moose hunter day expenditures as a proxy for "willingness to pay" (State of Wyoming 1980), the value of the hunting days lost because of the dam project was evaluated on the basis of an average hunting trip of ten days and expenditures of $327.24 per day for five moose hunters. Therefore, the loss of moose habitat would result in foregone benefits of $16,362 per year.

The disturbance of moose habitat represents an annual economic loss to the Pattengail Creek drainage of about $16,362. By subtracting this cost and the annual costs of constructing, operating, and maintaining the dam facility, the net economic benefits or losses can be evaluated.

Agriculture vs. Recreation

Not enough additional water can be supplied by the Pattengail project to satisfy the total demands of both agriculture and recreation. If agriculture received the total supply of water, it would annually derive approximately $448,768, or $44.26 per acre-foot, of additional value. In comparison, if the total supply were allocated to recreation and the fish population doubled, $345,069, or $34.03 per acre-foot, of additional value would be derived. Given the assumptions of this study, the use of this additional supply of water for agriculture would have the highest value.

Table IV-8 shows the added benefits and costs of the project as water is allocated between agriculture and recreation. In each case, a net economic loss is indicated.

Table IV-8. Added benefits and costs as the supply of water is distributed between agricultural and recreational uses.

Benefits/ Costs ($)	Portion of water supply allocated to recreation 100%	75%	50%	25%	0%
Recreation	$ 345,069	$ 258,802	$ 172,535	$ 86,267	$ 0
Agriculture	0	112,192	224,384	336,576	448,768
Total benefits	345,069	370,994	396,919	422,843	448,768
Dam cost	1,119,678	1,119,678	1,119,678	1,119,678	1,119,678
Moose habitat	16,362	16,362	16,326	16,362	16,362
Net Loss	$ 790,971	$ 765,046	$ 739,085	$ 713,197	$ 687,272

Chapter V

SOURCES OF FUNDING

Potential sources of funds for the Pattengail project include a number of state and federal programs as well as private sources.

Federal funding could come from the U.S. Forest Service, for watershed protection; the Consolidated Farm and Rural Development Program and the Soil and Water Loans Program, administered by the Farmers Home Administration (FmHA); the Small Watershed Program, administered by the Soil Conservation Service (SCS); and the Small Reclamation Projects Program, administered by the Bureau of Reclamation. Possible sources of state funding are: the Water Development Program and the Renewable Resource Development Program, administered by the Department of Natural Resources and Conservation (DNRC); and coal severance tax bonds under the authority of the Montana Legislature.

In order for the U.S. Forest Service to provide funds, a project must directly benefit the adjacent national forest or it must aid in watershed protection. The Pattengail project does not meet either of these requirements. In fact, if the project is developed, payments may have to be made to the Forest Service as mitigation for lost wildlife habitat.

The Consolidated Farm and Rural Development and Soil and Water Loans programs, administered by FmHA, are sources of guaranteed loans for projects similar to the Pattengail facility. However, the limits on these loans are small compared to the estimated costs of the Pattengail project. Thus, they would provide little financial assistance.

The Small Watershed Program, administered by the SCS, can provide financial aid for projects of the size and cost of the Pattengail project. Because one of the purposes of the Pattengail project would be to provide supplemental water for irrigation, a maximum 50 percent cost-share arrangement for construction would be possible. However, a couple of problems limit the possibility of obtaining funds from this source. These are that: 1) only projects with benefit/cost ratios greater than 1 can be con- sidered for funding from the Small Watershed Program. It appears that the benefit/cost ratio for Pattengail would be considerably less than 1, given the current information; and 2) Small Water- shed Program projects have been held up by the federal Office of Management and Budget for the past several years.

The Small Reclamation Projects Program, administered by the Bureau of Reclamation, can provide loans and/or grants of up to $21.6 million for projects like Pattengail. Grants can be awarded for the amount of benefits in the areas of flood control,

outdoor recreation, and fish and wildlife habitat enhancement -- as long as these benefits are available to the public. Also, grants may be awarded even though no loan is requested -- as long as the project is multipurpose. For project loans, limits on acres irrigated from federally financed water projects determine the interest rate. For the portion of a loan used for irrigation service within the current acreage limits on private lands, there is no interest. For the portion of a loan used for irrigation service in excess of the private acreage limits, there is an interest charge.

Although this program is a likely source of funds for the Pattengail project, several problems reduce the potential for timely funding. For instance, economic analyses of the project must show that its construction is financially feasible. Currently, this is not the case for Pattengail. In addition, the allocation of funds to applicants who already have completed the process for Small Reclamation Projects loans has been delayed by the Secretary of the Interior until more money is available.

The Water Development Program, created in 1981 by the 47th Montana Legislature, is administered by DNRC. Its purpose is to promote and advance the beneficial use of water by funding water development projects and activities. Funds for the program come from a percentage of the revenues from the state's coal severance tax -- about $1.5 million each biennium. These funds are used in the form of grants and/or loans for qualifying public and private projects. DNRC also can issue up to $5 million in general obligation bonds to provide additional monies for loans.

The Pattengail project is larger in scope than the kind of project the Water Development Program is intended to fund. However, the program could be a source of funds for further feasibility analyses or partial funding of the project.

The Renewable Resource Development (RRD) Program, created by the Legislature in 1975 and administered by DNRC, promotes the development of Montana's renewable resources by providing loans and grants for qualifying projects. The RRD program is funded with the same percentage of the coal severance tax revenues as the Water Development Program. General obligation bonds may be issued for RRD projects. However, only 40 percent of these funds may be used for water-related projects -- that is, approximately $600,000 in direct funding and $2 million in bonding authority are available for water projects each biennium. The Legislature makes the final decision on projects funded through the RRD program.

The total amount of funds available to the RRD program each biennium is small when compared to the costs of the Pattengail project. However, the RRD program could be a source of funds for further feasibility analyses or partial funding of the project.

For a project of Pattengail's scale, coal severance tax bonds appear to have the best potential for significant funding from a state source. As part of the act to create the Water Development Program, the Montana Legislature authorized a procedure whereby coal severance tax bonds could be sold to finance water resource development projects and activities. Although the Legislature set a maximum of $250 million in bonds for this use, there is no statutory limit on the amount of funds within this total that can be used to finance an individual project. In addition, the Legislature has the option to repay all or part of the bonds with coal tax revenues that could be used to subsidize a project.

In addition to federal and state sources, some funds might be obtained from private sources. The Big Hole River is held in the highest esteem by sportsmen nationwide. Thus, it may be possible to solicit funds from state and national sportsmen's groups and wildlife associations. Because severe water shortages in the Big Hole River Basin have sometimes reduced carry-over fish populations (Wells and Decker-Hess 1981), these groups may be interested in participating in the project. It is unlikely, however, that a significant portion of the project's cost could be obtained from these sources.

It should be noted that those portions of the project's total cost financed through loans would almost certainly have to be repaid by water users.

In summary, because the current economic outlook for the Pattengail project makes it a poor competitor for available funds, it will probably be difficult to obtain major funding from existing sources.

Chapter VI

WATER RIGHTS AND WATER MANAGEMENT IN THE BIG HOLE RIVER BASIN

The high cost of water storage at Pattengail Creek reduces the appeal of a structural solution to the periodic water shortage problems in the Big Hole River Basin. An alternative approach to the problem -- one that has not yet been examined in detail -- is a form of water management that relies on two components: 1) the adjudication and enforcement of water rights, and 2) the imple- mentation of water conservation practices that mitigate the effects of insufficient water supplies. Although this approach has potential, its practicality for the Big Hole River Basin is uncertain without detailed investigations.

The adjudication of water rights in the Big Hole River Basin will generate data on water use in the basin and the priority and amount of water held by each right holder. Adjudication and enforcement of these rights could mean that the periodic water shortages would shift in location or be spread more evenly within the basin. Either result would depend on the location of senior water rights. If a significant number of senior water rights exists along the lower reach of the river, and these rights are enforced, it is possible that the periodic dewatering now occurring in the lower Big Hole River Basin would be alleviated.

A coordinated adjudication of Big Hole River Basin water rights is now part of the ongoing state effort to document existing water rights and uses in Montana. With the passage of Senate Bill 76 in 1979, all existing water rights claims were required to be filed with the Department of Natural Resources and Conservation (DNRC) by April 30, 1982. The legislation also authorized water judges to preside over the adjudication of these rights.

DNRC estimates that 1,600 claims for water in the Big Hole River Basin have been filed. These claims are being reviewed for completeness and will be entered into a state computer file -- a process that should be complete by July 1983. At some subsequent date, the courts will issue a preliminary decree of the rights in each basin, hold hearings, and issue a final decree. Even with a priority and available resources, the complete adjudication of a basin could take at least three years.

For various reasons, priority has been given to the adjudication of water rights in a number of river basins within the Big Hole River's division (Upper Missouri Division). Since the Big Hole River Basin does not have a priority, the adjudication of water rights there may be years away. If the adjudication process is to be used in reexamining the water shortage problems in the near future, priority would have to be given to the adjudication of water rights in the Big Hole River Basin.

Unless the rights are enforced, a final decree on water rights in the Big Hole River Basin may not have much effect on the current water shortages. However, enforcement is not an automatic process. In order to enforce a decreed right, local water rights holders must petition a district court to appoint a water commissioner. Water rights holders representing at least 15 percent of the decreed waters must participate in the petition process. The court then appoints a water commissioner and any necessary assistants to settle the conflict. Water commissioners are not appointed on an annual basis, but are assigned by a court when a conflict arises.

The costs of enforcement are dictated by the court and the specific situation. For example, a water commissioner for the West Gallatin River has cost $50 to $60 per day (Lessley 1982). Although costs may vary, a standard procedure for billing each water rights holder is followed -- at the end of each irrigation season, each user is billed a prorated share of the costs based on actual water use.

While water rights enforcement may cause some changes in the location of water shortages, it is possible that there still will be a need for water to augment low flows. As part of the water management approach, water conservation practices would be implemented to at least partially offset periodic shortages. These practices could not occur without some economic justification to the water user. In order to make conservation affordable to the water user, financial assistance may be necessary. Such assistance could come from the Montana Water Development Program, for example.

Several areas would have to be investigated to determine the practicality of the water rights/water management approach. These investigations would include a technical investigation of the usefulness of water conservation measures in the Big Hole River Basin and an assessment of the willingness of area water users to accept the water conservation approach and the types of assistance necessary to encourage its implementation. The investigation would also include a preliminary review of basin water rights and potential effects of water rights enforcement.

Chapter VII

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The earthfill dam originally proposed for the Pattengail Creek site by a consultant for DNRC, and recommended in the report prepared for the 1981 Montana Legislature, is not feasible. Enough material suitable for use as fill in an earthen dam is not available within an economic hauling distance of the site.

2. Based on current information, a safe structure can be constructed on Pattengail Creek. This structure would be a rockfill dam with a slurry trench, a concrete face on the upstream side, an ungated concrete chute service spillway, a grass-lined auxiliary spillway, and a concrete conduit-type outlet. A structure of this type would cost approximately $14.4 million (July 1982 dollars). The estimated cost of such a structure is over three times the consultant's original estimate for an earthfill dam at the site ($4.2 million in July 1982 dollars).

3. If a final design for a dam at Pattengail Creek is developed, additional technical studies must be conducted. These studies would include a detailed seismic evaluation of site conditions to ensure a safe design, with particular attention to the talus slope above the right abutment and the potential liquefaction of lake sediments under the proposed dam axis. Additional subsurface investigations in the area of the right abutment would include at least two drill holes into bedrock in order to determine the depth of talus and location of the talus-till interface.

4. The rockfill dam at the Pattengail Creek site is not economically feasible under present conditions. The total annual cost of the dam would be $1,136,310. Of this, $1,119,678 are direct costs associated with the operation and maintenance of the facility; $16,632 is the estimated annual cost of the moose habitat lost to the reservoir. Even disregarding the cost of lost moose habitat, water from the Pattengail dam would cost $110.42 per acre-foot, based on the firm average annual yield of the reservoir.

   Given the assumptions used in this study's economic analysis, agricultural use of the stored water would give the greatest return per acre-foot. The benefits of agricultural use are estimated to be $44.26 per acre-foot. Use of the reservoir water only for instream uses would yield $34.03 per acre-foot in benefits. Various combinations of agriculture and instream water use would give returns between the values for agriculture or instream use. Therefore, even if all the stored water were allocated to agriculture, the operation of

the reservoir would result in an annual net loss of $66.16 per acre-foot, or $670,862.

5. Water rights/water management is a potential alternative solution to the periodic water shortages in the Big Hole River Basin. Further investigation is necessary to determine the practicality of this approach.

Recommendations

1. The Pattengail Creek dam site should not at this time receive further consideration as a viable solution to the recurring water shortage problems in the Big Hole River Basin.

2. If a water rights/water management approach to resolving water shortages in the Big Hole River Basin is pursued, the adjudication of water rights in the basin should be given priority by the courts.

Appendix A

Geologic Study Data

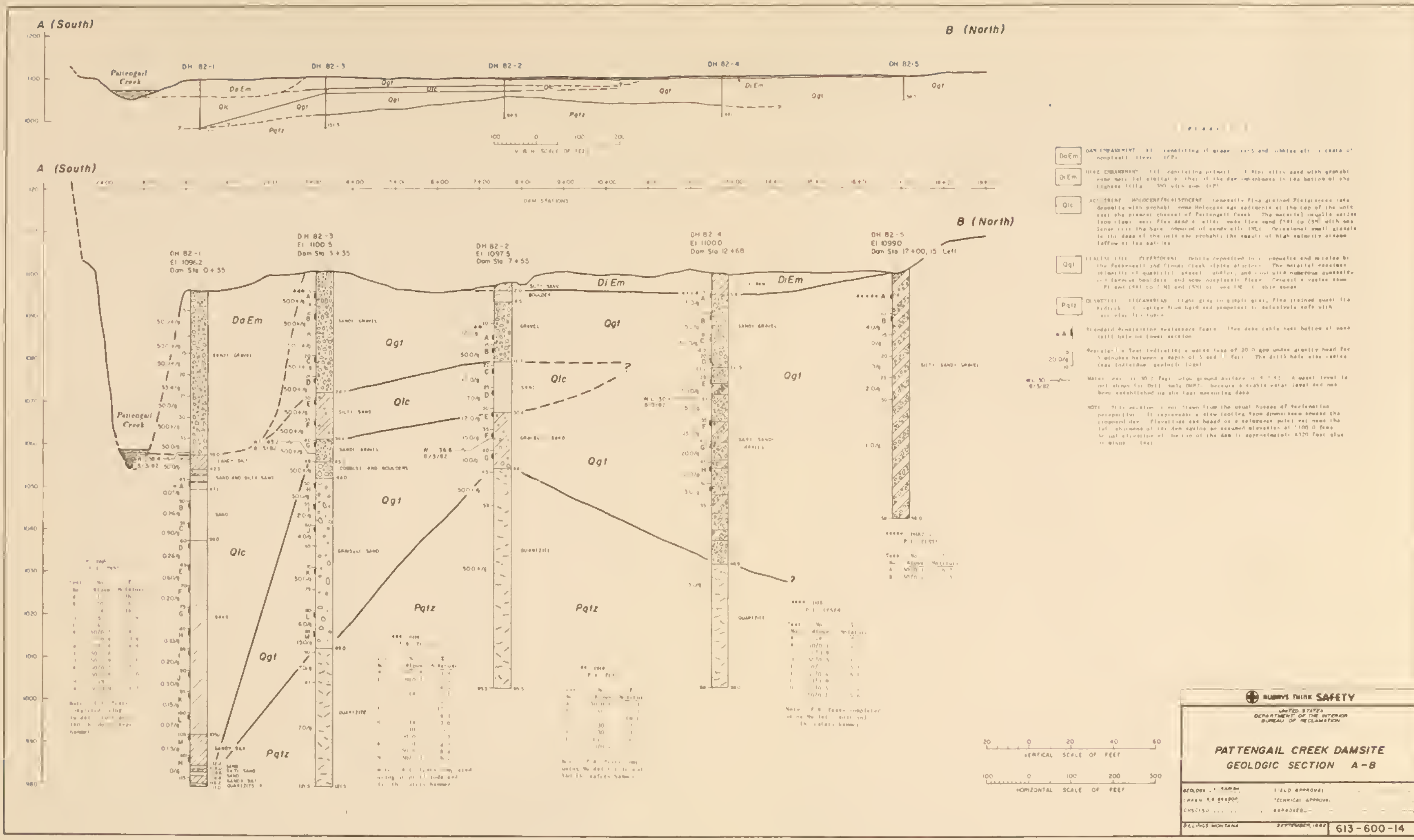


FIGURE A PATTENGAIL CREEK GEOLOGIC SECTION

SOURCE: U. S. Bureau of Reclamation

7-1337 (6-71)
Water and Power

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Pattengail Creek Damsite PROJECT .... STATE Montana

HOLE NO. DH82-1 LOCATION Dam Sta. 0+35' Centerline COORDS. N. .... E. .... GROUND ELEV. ** 1096.2+ DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 6-16-82 FINISHED 6-28-82 DEPTH OF OVERBURDEN .... TOTAL DEPTH 117.0' BEARING ....

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY ....

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

DRILL
Mobile B-50 truck-mounted.
DRILLER
Clarence Swanson (Montana Highway Department)
METHOD
Nx casing drive sample 0 to 5'. Bx casing drive samples 5 to 25'. 2" split spoon drive samples 25 to 28.4'. Ax diamond core 28.4 to 30'. 2" split spoon drive sample 30 to 31.5'. Ax diamond core 31.5 to 33.7'. 2" split spoon drive samples 33.7 to 116.2'. Washed with quarry bit 116.2 to 117'. Could not drill through rock at 117' and abandoned hole. PR Tests taken at 5' intervals from 45.5 to 111.5'. Clear water used as drill fluid. Gravity tests taken at 5' intervals. Water losses in excess of 50 gpm at times when cleaning out casing between drives. Hole caved throughout entire depth. PR Tests taken using Aw drill rods and a donut type non-standard 140 pound hammer dropped 30".
CASING RECORD
Set Nx casing in 5' lengths to 117' to prevent caving. Pulled all casing on completion of hole.

Depth	Date
0-40'	6-16-82
40-60'	6-17-82
60-85'	6-21-82
85-100'	6-22-82
100-117'	6-23-82

TYPE AND SIZE OF HOLE: NX, BX, 2", AX, 2", AX, 2"

CORE RECOVERY (%): 40, 0, 20, 30, 0, 25, 21, 12, 40, 16, 0, 24, 80, 80, 100, 67, 75, 67, 87, 75, 67, 100, 75, 67, 67, 75, 67, 100, 75, 67, 100, 75, 67, 100, 75, 67, 67, 75, 67, 67, 75, 50, 100, 100, 35, 100, 100

PERCOLATION TESTS

Depth (feet) From (P, Cs, or Cm)	To	Loss (G.P.M.)	Pressure (P.S.I.)	Length of Test (Min.)
5 Cs	11	* 50.0+	grav.	5
11 Cs	15	50.0+	grav.	5
15 Cs	20	50.0+	grav.	5
19 Cs	25	33.4	grav.	5
25 Cs	30	50.0	grav.	5
30 Cs	35	50.0+	grav.	5
35 Cs	40	50.0	grav.	5
40 Cs	45	50.0	grav.	5
45 Cs	50	0.07	grav.	5
50 Cs	55	0.26	grav.	5
55 Cs	60	0.9	grav.	5
60 Cs	65	0.26	grav.	5
65 Cs	70	0.6	grav.	5
70 Cs	75	0.2	grav.	5
80 Cs	85	0.1	grav.	5
85 Cs	90	0.2	grav.	5
90 Cs	95	0.3	grav.	5
95 Cs	100	0.15	grav.	5

Elevation (feet)	Depth (feet)
1057.2	39.0
1053.7	42.5
1049.2	47.0
1037.2	59.0

CLASSIFICATION AND PHYSICAL CONDITION

0-39.0' SANDY GRAVEL (EMBANKMENT): approx. 60% fine to coarse subangular to subrounded gravel; 10% subangular to subrounded cobbles to at least 10" diameter; 30% mostly fine sand; trace of nonplastic fines; damp to moist at depth; loose; no HCl reaction; tan to brown with gray and purple-gray quartzite gravel and cobbles. (GP)

HOLOCENE-PLEISTOCENE-(LACUSTRINE)

39.0-42.5' SANDY SILT: approx. 80% nonplastic fines; 20% very fine sand; saturated; soft and mushy; organic (several small pieces of rotten wood); varved; no HCl reaction; dark gray to black. (ML)

42.5-47.0' SAND AND SILTY SAND: alternating 2 to 3" lenses of clean, fine sand with ¼" layers of organic, silty (approx. 30% nonplastic fines) sand; saturated; soft; no HCl reaction; dark gray sand with nearly black silty sand layers. (SP) with (SM)

47.0-59.0' SAND: approx. 100% predominantly fine quartz sand; saturated; loose; no HCl reaction; gray. (SP)

59.0-105.0' SAND: approx. 90% extremely fine sand (+200 sieve size); 10% nonplastic fines; saturated; soft; varved; no HCl reaction; tan. (SP-SM)
Note: Percentage of fines may be greater or less. Hard to field log due to small sand size.

105.0-112.2' SANDY SILT: approx. 80% nonplastic fines; 20% very fine sand; saturated; soft; varved; no HCl reaction; tan. (ML)

112.2-113.0' SAND: approx. 95% predominantly fine to medium sand; 5% nonplastic fines; scattered subangular to subrounded gravel to ½"; saturated; loose; no HCl reaction; light brown. (SP)

113.0-113.8' SILTY SAND: approx. 60% fine sand; 40% nonplastic fines; one 1½" subangular gravel at 113.4'; saturated; crumbly; no HCl reaction; tan. (SM)

113.8-114.5' SAND: approx. 95% fine to coarse sand; 5% nonplastic fines; scattered subangular gravel to ½" diameter; saturated; loose; no HCl reaction; light brown. (SP)

PLEISTOCENE-(GLACIAL TILL?)

114.5-116.2' SANDY SILT WITH GRAVEL: approx. 90% nonplastic fines; 10% very fine sand; occasional (three) subrounded quartzite gravels to 1-1/8"; saturated; soft; no HCl reaction; tan. (ML)

116.2-117.0' QUARTZITE (COBBLES, BOULDER OR BEDROCK): no recovery. Driller reported sandy gravel with a boulder.

EXPLANATION

CORE LOSS / CORE RECOVERY

* 50.0 gpm maximum capacity of hose from water truck. During some embankment gravity tests 50.0 gpm would not keep casing full.

** All elevations are based on a reference bar with an assumed elevation. Actual elevation of top of dam is about 6320' +.

Type of hole .... D = Diamond, H = Hawstellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = bottom of casing
Approx. size of hole (X series) ... Ex = 1 1/2", Ax = 1 7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X series) ... Ex = 7/8", Ax = 1 1/8", Bx = 1 5/8", Nx = 2 1/8"
Outside dia. of casing (X series) ... Ex = 1-13/16", Ax = 2 1/4", Bx = 2-7/8", Nx = 3 1/2"
Inside dia. of casing (X series) ... Ex = 1 1/2", Ax = 1 29/32", Bx = 2-3/8", Nx = 3"

FEATURE Pattengail Creek Damsite PROJECT .... STATE Montana SHEET 1 OF 2 HOLE NO. DH82-1

GEOLOGIC LOG OF DRILL HOLE

FEATURE Pattengail Creek Damsite PROJECT ..... STATE Montana

HOLE NO. DH82-1 LOCATION Dam Sta. 0+35' Centerline COORDS. N. ..... E. ..... GROUND ELEV. ** 1096.2+ DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 6-16-82 FINISHED 6-28-82 DEPTH OF OVERBURDEN ..... TOTAL DEPTH 117.0' BEARING .....

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY .....

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Pulled all casing 6-24 and 6-28-82.

PROGRESS RECORD

See casing notes above.

HOLE COMPLETION

Set plastic pipe to 117'. Bottom 40' perforated. Pulled casing. Set capped metal riser at surface. Back-filled at surface with cuttings and embankment.

PENETRATION TESTS

See far right column.

WATER LEVELS

Depth	Date
36.3'	6-24-82
36.7'	6-28-82
36.7'	6-30-82
37.5'	7-8-82
37.9'	7-15-82
38.0'	7-21-82
38.4'	7-29-82
38.4'	8-3-82

TYPE AND SIZE OF HOLE: Wash (to 117)

CORE RECOVERY (%): 75, 100, 100, 50, 80, 80, 50, 67, 67, 50, 0

PERCOLATION TESTS

From (P, Cs, or Cm) (feet)	To (feet)	Loss (G.P.M.)	Pressure (P.S.I.)	Length of Test (Min.)
100 Cs	105	0.07	grav.	5
105 Cs	110	0.75	grav.	5
110 Cs	115	1.0	grav.	5

Elevation (Feet)	Depth (Feet)
991.2	105.0
984.0	112.2
983.2	113.0
982.4	113.8
981.7	114.5
980.0	116.2
979.2	117.0

CLASSIFICATION AND PHYSICAL CONDITION

Could not drill deeper with the tools available.

PENETRATION TESTS

Depth	No. Blows Per Foot	Moisture Content %
45.5-46.5'	17	36.1
50.5-51.5'	20	26.5
55.5-56.5'	18	39.5
60.5-61.5'	35	27.9
65.5-66.5'	42	27.2
70.5-71.5'	71	26.1
75.5-76.5'	54	20.9
80.5-81.5'	60	19.9
85.5-86.5'	63	24.1
90.5-91.5'	58	21.6
95.5-96.5'	74	20.5
100.5-101.5'	59	22.0
105.5-106.5'	49	25.2
110.5-111.5'	57	16.5

All penetration tests taken using 140 pound donut type hammer and Aw drill rods.

EXPLANATION

** See page 1.

CORE LOSS / CORE RECOVERY

Type of hole ..... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed ..... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

7-1337 (9-69)
Bureau of Reclamation GPO 884-401

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Pattengail Creek Damsite PROJECT STATE Montana
HOLE NO. DH82-2 LOCATION Dam Sta. 7+55 Centerline GROUND ELEV. ** 1097.5'± DIP (ANGLE FROM HORIZ.) Vertical
COORDS. N. E.
BEGUN 6-29-82 FINISHED 7-7-82 DEPTH OF OVERBURDEN TOTAL DEPTH 95.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

DRILL
Mobile B-50 truck-mounted.

DRILLER
Clarence Swanson (Montana Highway Department)

METHOD
Nw casing drive sample 0-2'. Nx drive sample 2'-4.5'. 2" split-spoon drive sample 4.5-6.7'. Wash sample 6.7-10'. 2" split-spoon 10-32'. Wash sample 32-35'. 2" split-spoon drive 35-37'. Wash sample 37-40'. 2" split-spoon drive 40-42'. Drilled with 2-15/16" rockbit 42-45.5'. Cored with Nx 45.5-95.5'. PR tests taken at 5' intervals. Clear water used as drill fluid. Gravity tests taken at 5' intervals. Water losses often in excess of 50 gpm. Hole caved until bedrock reached. Bedrock extremely broken. PR tests taken using Nw drill rods and a standard 140 lb. Safety hammer dropped 30".

CASING RECORD
Set Nx casing in 5' lengths to 44'. Pulled all casing 7-7-82.

Depth	Date
0-15'	6-29-82
15-44'	6-30-82

PROGRESS RECORD

Depth	Date
0-20'	6-29-82
20-45'	6-30-82
45-56.1'	7-1-82
56.1-95.5'	7-6-82
Completion	7-7-82

HOLE COMPLETION
Set plastic pipe to 95.5'. Bottom 40' perforated. Pulled casing.

TYPE AND SIZE OF HOLE / CORE RECOVERY (%)

Type and size of hole	Core recovery (%)
Nw	75
Nx	60
2"	0
	67
Wash	0
2"	50
	67
	40
	25
	33
	60
	40
	13
	33
	50
	73
	100
	60
Wash	0
2"	75
Wash	0
2"	60
Wash	0
Nx Core	100
	100
	90
	85
	90
	70
	80
	100
	100
	100
	100

PERCOLATION TESTS

From (P, Cs, or Cm)	To	Loss (G.P.M.)	Pressure (P.S.I.)	Length of test (Min.)
10 Cs	15	12.0	grav.	5
15 Cs	20	50.0	grav.	5
20 Cs	25	12.0	grav.	5
25 Cs	30	7.0	grav.	5
30 Cs	35	12.0	grav.	5
35 Cs	40	15.0	grav.	5
40 Cs	45	10.0	grav.	5
44 Cs	53	* 50.0+	grav.	5
44 Cs	95.5	50.0+	grav.	5

Note: Could not keep hole filled with 50 gpm water hose between 44.0 and 95.5'

ELEVATION (FEET) / DEPTH (FEET)

Elevation	Depth
1095.5	2.0
1093.0	4.5
1078.8	18.7
1066.9	30.6
1053.5	44.0
1002.0	95.5

CLASSIFICATION AND PHYSICAL CONDITION

PLEISTOCENE - (GLACIAL TILL)
0-2.0' SILTY SAND: approx. 60% mostly fine sand; 35% nonplastic fines; 5% subangular gravel to 1½"; damp; crumbly; some tree roots; pine needles in top 2"; no HCl reaction; brown. (SM)
2.0-4.5' BOULDER: purple-gray quartzite; hard; broken.
4.5-18.7' GRAVEL: approx. 50% fine to coarse, subangular to subrounded mostly quartzite gravel; 10% cobbles to 12"; 35% fine to coarse sand; 5% nonplastic fines; moist; loose; no HCl reaction; tan to light brown. (GP)

PLEISTOCENE - (LACUSTRINE?)
18.7-30.6' SAND: approx. 95% very fine sand; 5% nonplastic fines; scattered, mostly angular rock fragments to 1"; moist; loose; no HCl reaction; tan. (SP)

PLEISTOCENE - (GLACIAL TILL)
30.6-44.0' GRAVELLY SAND: poor recovery; approx. 60% mostly fine to medium sand; 30% mostly subangular quartzite gravel to 1½"; 10% nonplastic fines; scattered cobbles; wet; loose; no HCl reaction; gray to 35'; rusty brown to 40'; tan to 44'. (SP-SM)

PRECAMBRIAN - BELT SERIES
44.0-95.5' QUARTZITE: gray to rusty gray and purple-gray; core badly broken by rust stained fractures dipping at all degrees, but mostly from 45 to near 90°; the core has almost a "spider web" appearance caused by fractures; relicit bedding dips about 30°, but has some cross bedding; some zones have more of a sandstone composition than a quartzitic; core seldom averages more than 1-3" angular broken pieces; possible poorly developed slickensides on some core breaks; a few 6" to 1' zones appear to contain fine grained gouge; wet; no HCl reaction.

Note: RQD equals 0% for all core runs except:

Depth	Percent
45.5-48.5'	14
48.5-53.0'	29
84.7-90.5'	7
93.0-95.5'	24

PENETRATION TESTS

Depth	No. Blows per Foot	Moisture Content
12.5-13.5'	59	12.9
15.5-16.5'	40	6.0
20.5-21.5'	22	19.1
25.5-26.5'	30	12.7
30.5-31.5'	30	10.2

EXPLANATION

* 50.0 gpm maximum capacity of hose from water truck. During some percolation tests 50.0 gpm would not keep casing full.

** All elevations are based on a reference bar with an assumed elevation. Actual elevation of top of dam is about 6320'±.

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Pattengail Creek Damsite PROJECT STATE Montana SHEET 1 OF 2 HOLE NO. DH82-2

7-1337 (9-69)
Bureau of Reclamation GPO 864-401

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Pattengail Creek Damsite PROJECT STATE Montana

HOLE NO. DH82-2 LOCATION Dam Sta. 7+55 Centerline GROUND ELEV. ** 1097.5'± DIP (ANGLE FROM HORIZ.) Vertical

COORDS. N. E.

BEGUN 6-29-82 FINISHED 7-7-82 DEPTH OF OVERBURDEN TOTAL DEPTH 95.5' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Set capped 2½" steel pipe to 5' as surface protection. Backfilled at surface with cuttings.												PENETRATION TESTS (Cont'd)

Notes column (continued):

PENETRATION TESTS

See far right column.

WATER LEVELS

Depth	Date
35.6'	7-15-82
36.0'	7-21-82
36.5'	7-29-82
36.6'	8-3-82

PENETRATION TESTS (Cont'd)

Depth	No. Blows per Foot	Moisture Content
35.5-36.5'	69	6.5
40.5-40.9'	50/0.4	5.5

Depth scale: 10, 20, 30, 40, 50, 60, 70, 80, 90

** See page 1.

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole . . . . . D = Diamond, H = Hoystoilite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1 7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Pattengail Creek Damsite PROJECT STATE Montana SHEET 2 OF 2 HOLE NO. DH82-2

7-1337 (6-74)
Water and Power

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Pattengall Creek Damsite PROJECT .... STATE Montana

HOLE NO. DH82-3 LOCATION Dam Sta. 3+35 Centerline COORDS. N. .... E. .... GROUND ELEV. ** 1100.5'± DIP (ANGLE FROM HORIZ.) Vertical

BEGUN 7-7-82 FINISHED 7-19-82 DEPTH OF OVERBURDEN .... TOTAL DEPTH 121.5' BEARING ....

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY ....

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

DRILL
Mobile B-50 truck-mounted.
DRILLER
Clarence Swanson (Montana Highway Department)
METHOD
2-15/16" rockbit wash sample 0-5'. 2" split spoon drive 5-7.8'. 2-15/16" rockbit wash 7.8 to 10'. 2" split spoon drive 10 to 15.3'. 2-15/16" rockbit wash 15.3 to 20'. 2" split spoon drive 20 to 45'. Nx core 45 to 49'. 2" split spoon drive 49 to 65'. 2-15/16" rockbit wash 65 to 70'. 2" split spoon drive 70 to 71.6'. 2-15/16" rockbit wash 71.6 to 80'. 2" split spoon drive 80 to 80.6'. 2-15/16" rockbit wash 80.6 to 85'. 2" split spoon drive 85 to 86.3'. 2-15/16" rockbit wash 86.3 to 90.2'. Ax diamond core 90.2 to 121.5'. PR tests taken at 5' intervals where possible. Clear water used as drill fluid. Gravity tests taken as shown. Some water losses in excess of 50 gpm. PR tests completed using Nw drill rods and a standard 140 lb. safety hammer dropped 30".
CASING RECORD
Set Nx casing in 5' lengths to 89'. Pulled all casing 7-19-82.

TYPE AND SIZE OF HOLE / CORE RECOVERY (%)

Type and size of hole	Core recovery (%)
Wash	0
2"	25, 88
Wash	0
2"	35, 47, 55, 15
Wash	0
2"	25, 40, 47, 25, 40, 67, 25, 40, 47, 75, 33, 100, 25, 47, 33
Nx	25
2"	0, 40, 33, 47, 10, 27, 20, 40, 67, 67
Wash	0
2"	44
Wash	0
2"	33
Wash	0
2"	31
Wash	0
Ax	95, 80, 50, 65, 35

PERCOLATION TESTS

Depth (feet) From (P, Cs, or Cm)	To	Loss (G.P.M.)	Pressure (P.S.I.)	Length of test (min.)
5Cs	8	* 50.0+	grav.	5
10Cs	15	50.0+	grav.	5
15Cs	20	50.0+	grav.	5
20Cs	25	50.0+	grav.	5
25Cs	30	50.0+	grav.	5
30Cs	35	50.0+	grav.	5
35Cs	40	50.0+	grav.	5
40Cs	45	50.0+	grav.	5
45Cs	50	50.0+	grav.	5
50Cs	55	30.0	grav.	5
55Cs	60	2.0	grav.	5
60Cs	65	4.0	grav.	5
70Cs	75	50.0	grav.	5
80Cs	85	6.0	grav.	5
85Cs	90	15.0	grav.	5
89Cs	97	7.0	grav.	5

Elevation (feet)	Depth (feet)
1071.8	28.7
1060.9	39.6
105 .5	45.0
1051.5	49.0
1011.5	89.0

GRAPHIC LOG | SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

PLEISTOCENE

0-28.7' SANDY GRAVEL (GLACIAL TILL): approx. 60% subangular to subrounded mostly quartzite gravel to 3"; 40% fine to coarse sand; numerous cobbles and boulders; trace of nonplastic fines; moist; no HCl reaction; gray to purple-gray gravel with mostly tan sand. (GP)

28.7-39.6' SILTY SAND (LACUSTRINE?): approx. 90% very fine sand; 10% nonplastic fines; moist; loose to crumbly; apparent near horizontal varving in some zones; possibly 5% subrounded quartzite gravel to 2" from 32 to 33'; also a trace of gravel to 1" below 37'; no HCl reaction; tan. (SP-SM)

39.6-45.0' SANDY GRAVEL (GLACIAL TILL): approx. 55% subangular to subrounded mostly quartzite gravel to 3"; 40% fine to coarse sand; 5% nonplastic fines; scattered cobbles; moist; crumbly to loose; no HCl reaction; tan sand with gray and purple-gray gravel. (GP)

45.0-49.0' COBBLES AND BOULDERS: hard, gray quartzite.

49.0-89.0' GRAVELLY SAND (GLACIAL TILL): poor recovery; approx. 55% fine to coarse sand; 45% subangular to subrounded mostly quartzite gravel to 3"; scattered zones of gravel and zones containing fine sand and up to 5% nonplastic fines moist; loose; no HCl reaction; tan to brown. (SP)

PRECAMBRIAN - BELT SERIES

89.0-121.5' QUARTZITE: light gray; hard; Ax core broken into short lengths due to small diameter and drill breakage; core lengths average about 1½" and range from about ½" to a maximum of 3"; occasional high angle (dips to 70°-90°) oxidized joints; relict bedding is sometimes crossbedded, but usually dips about 30°; no HCl reaction.

NOTE: Hole was too crooked to use a core barrel larger than Ax, therefore no RQD can be computed. However, the rock appears quite hard and competent with no excessive water losses noted in the percolation tests.

EXPLANATION

CORE LOSS / CORE RECOVERY

* 50.0 gpm maximum capacity of hose from water truck. During some percolation tests 50.0 gpm would not keep casing full.

** All elevations are based on a reference bar with an assumed elevation. Actual elevation of top of dam is about 6320'±.

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1 2", Ax = 1 7 8", Bx = 2-3 8", Nx = 3"
Approx. size of core (X series) .. Ex = 7 8", Ax = 1-1 8", Bx = 1 5 8", Nx = 2 1 8"
Outside dia. of casing (X-series) . Ex = 1 13 16", Ax = 2-1 4", Bx = 2 7 8", Nx = 3 1 2"
Inside dia. of casing (X series) .. Ex = 1 1 2", Ax = 1 29 32", Bx = 2 3 8", Nx = 3"

FEATURE Pattengall Creek Damsite PROJECT ...... STATE Montana SHEET 1 OF 2 HOLE NO DH82-3

7-1337 (6-74)
Water and Power

GEOLOGIC LOG OF DRILL HOLE

FEATURE Pattengail Creek Damsite PROJECT STATE Montana
HOLE NO DH82-3 LOCATION Dam Sta. 3+35 Centerline COORDS. N. E. GROUND ELEV. ** 1100.5'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7-7-82 FINISHED 7-19-82 DEPTH OF OVERBURDEN TOTAL DEPTH 121.5' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Depth	Date
0-15'	7-7-82
15-35'	7-8-82
35-60'	7-12-82
60-85'	7-13-82
85-89'	7-15-82

PROGRESS RECORD

Depth	Date
0-15'	7-7-82
15-35'	7-8-82
35-65'	7-12-82
65-85'	7-13-82
85-93.1	7-14-82
93.1-103.2	7-15-82
103.2-121.5	7-19-82

HOLE COMPLETION
Set plastic pipe to 121.5'. Bottom 40' perforated. Pulled casing. Set capped 2½" steel pipe to 5' as surface protection. Backfilled at surface with cuttings.

PENETRATION TESTS
See far right column.

WATER LEVELS

Depth	Date
42.5'	7-15-82
43.0'	7-19-82
42.8'	7-21-82
43.1'	7-29-82
43.2'	8-3-82

TYPE AND SIZE OF HOLE / CORE RECOVERY (%)

Type and size of hole: Ax

Core recovery (%)
90
50
65
60
0
65
12
50
85
0
45

PERCOLATION TESTS

Depth (feet) From (P, Cs, or Cm)	To	Loss (G.P.M.)	Pressure (P.S.I.)	Length of test (MIN.)	Elevation (feet)	Depth (feet)
89Cs	121.5	7.0	grav.	5	979.0	121.5

Depth scale: 110, 120, 30, 40, 50, 60, 70, 80, 90

CLASSIFICATION AND PHYSICAL CONDITION

PENETRATION TESTS

Depth	No. Blows Per Foot	Moisture Content
5.5-6.3'	50/0.8'	3.9
10.5-11.2'	50/0.7'	4.4
20.5-21.5'	22	6.4
25.5-26.5'	19	7.7
30.5-31.5'	27	14.5
35.5-36.5'	7	17.5
40.5-41.5'	37	6.3
50.5-51.5'	39	7.0
55.5-56.5'	20	--
60.5-61.2'	50/0.7'	7.7
70.5-71.2'	50/0.7'	6.2
80.5-80.6'	50/0.1'	8.9
85.5-85.8'	50/0.3'	6.2

EXPLANATION

□ CORE LOSS
■ CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1 2", Ax = 1-7 8", Bx = 2-3 8", Nx = 3"
Approx. size of core (X series) . . Ex = 7 8", Ax = 1-1 8", Bx = 1-5 8", Nx = 2 1 8"
Outside dia. of casing (X series) . Ex = 1-13 16", Ax = 2-1 4", Bx = 2-7 8", Nx = 3-1 2"
Inside dia. of casing (X series) . Ex = 1-1 2", Ax = 1 29 32", Bx = 2-3 8", Nx = 3"

FEATURE Pattengail Creek Damsite PROJECT STATE Montana SHEET 2 OF 2 HOLE NO DH82-3

GEOLOGIC LOG OF DRILL HOLE

FEATURE Pattengail Creek Damsite PROJECT STATE Montana

HOLE NO. DH82-4 LOCATION Dam Sta. 12+68 Centerline GROUND ELEV. ** 1100.0'± DIP (ANGLE FROM HORIZ.) Vertical

COORDS. N. E.

BEGUN 7-20-82 FINISHED 7-26-82 DEPTH OF OVERBURDEN TOTAL DEPTH 98.0' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

DRILL
Mobile B-50 truck-mounted.

DRILLER
Clarence Swanson (Montana Highway Department)

METHOD
Nx casing drive sample 0-5'. 2" split spoon, drive 5-11.5'. 2 15/16" rockbit wash 11.5-15'. 2" split spoon drive 15-18.5'. 2 15/16" rockbit wash 18.5-20.2'. 2" split spoon drive 20.2-23.2'. 2 15/16" rockbit wash 23.2-25'. 2" split spoon drive 25-27.5'. 2 15/16" rockbit wash 27.5-30'. 2" split spoon drive 30-30.5'. 2 15/16" rockbit wash 30.5-35'. 2" split spoon drive 35-37.2'. 2 15/16" rockbit wash 37.2-40'. 2" split spoon drive 40-43.2'. 2 15/16" rockbit wash 43.2-45'. 2" split spoon drive 45-45.5'. 2 15/16" rockbit wash 45.5-46'. 2" split spoon drive 46-46.7'. 2 15/16" rockbit wash 46.7-50'. 2" split spoon drive 50-50.8'. 2 15/16" rockbit wash 50.8-98'. Driller had extreme problems getting core recovery because of cobbles and boulders. The PR tests are of little value, but were attempted where shown. Core could not be taken in the bedrock because casing could not be set to prevent caving above

TYPE AND SIZE OF HOLE / CORE RECOVERY (%)

Type and size of hole	Core recovery (%)
NX	70
2"	40
2"	53
2"	47
2"	27
Wash	0
2"	0
2"	20
Wash	0
2"	25
2"	50
Wash	0
2"	40
2"	100
Wash	0
2"	60
Wash	0
2"	65
2"	0
Wash	0
2"	25
2"	58
Wash	0
2"	60
2"	71
Wash	0
2"	58
Wash	0

PERCOLATION TESTS

Depth (feet) From (P, Cs, or Cm)	To	Loss (G.P.M.)	Pressure (P.S.I.)	Length of test (min.)
5Cs	10	5.0	grav.	5
10Cs	15	5.0	grav.	5
15Cs	18.5	50.0	grav.	5
20Cs	23.2	10.0	grav.	5
25Cs	30.0	50.0	grav.	5
30Cs	35.0	15.0	grav.	5
35Cs	40.0	15.0	grav.	5
40Cs	45.0	20.0	g.	5
45Cs	50.0	2.0	grav.	5
50Cs	55.0	3.0	grav.	5

Wash

NOTE: Water loss during drilling between 54 and 98' was about 3.0 gpm. A thin mud of water and Quik-Trol was used as drilling fluid below 54'.

Elevation (feet)	Depth (feet)
1094.2	5.8
1077.5	22.5
1031.1	68.9
1002.0	98.0

CLASSIFICATION AND PHYSICAL CONDITION

DIKE EMBANKMENT

0-5.8' SILTY SAND: approx. 80% very fine sand; 20% nonplastic fines; dry; loose; some sagebrush roots 0-1'; no HCl reaction; tan. (SM)

PLEISTOCENE - GLACIAL TILL

5.8-22.5' SANDY GRAVEL: approx. 60% subangular to subrounded mostly quartzite gravel to 3"; numerous cobbles and boulders; 40% fine to coarse sand; trace of nonplastic fines; damp to moist; loose; no HCl reaction; mostly gray gravel with tan and gray sand. (GP)

22.5-68.9' SILTY, SANDY GRAVEL: very little recovery; material is probably horizontally zoned; approx. 55% subangular to subrounded mostly quartzite gravel to 3"; numerous cobbles and boulders; 35% fine to coarse sand; 10% nonplastic fines; some zones probably contain up to 25% nonplastic fines; moist; loose to crumbly; no HCl reaction; varies from gray to tan or rusty tan. (GP-GM) to (GM)

PRECAMBRIAN - BELT SERIES

68.9-98.0' QUARTZITE: no recovery; only rockbit wash of fine grained, oxidized sand. Driller reported very hard drilling.

PENETRATION TESTS

Depth	No. Blows Per Foot	Moisture Content
5.5-6.5'	48	3.1
10.5-11.5'	53	4.5
15.5-16.5'	65	--
20.5-21.0'	50/0.5'	6.0
25.5-26.2'	50/0.7'	5.8
35.5-35.9'	50/0.4'	6.6
40.5-41.3'	50/0.8'	7.5
46.0-46.5'	50/0.5'	7.4
50.5-50.7'	50/0.2'	5.6

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

** All elevations are based on a reference bar with an assumed elevation. Actual elevation of top of dam is about 6320'±.

7-1337 (9-69)
Bureau of Reclamation
GPO 864-401

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Pattengail Creek Damsite PROJECT STATE Montana
HOLE NO. DH82-4 LOCATION Dam Sta. 12+68 Centerline COORDS. N. E. GROUND ELEV. ** 1100.0'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 7-20-82 FINISHED 7-26-82 DEPTH OF OVERBURDEN TOTAL DEPTH 98.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION

the bedrock. Clear water was used as drill fluid to 54'. Below 54' a thin mud using Quik-Trol was used. Gravity percolation tests taken as indicated. PR tests attempted using Nw drill rods and standard 140 lb. safety hammer.

CASING RECORD

Set Nx casing in 5' lengths to 54'. Could not drive casing past rock at that depth. Pulled casing on 7-26-82.

Depth	Date
0-25'	7-20-82
25-50'	7-21-82
50-54'	7-22-82

PROGRESS RECORD

Depth	Date
0-30'	7-20-82
30-50'	7-21-82
50-55'	7-22-82
55-98'	7-26-82

HOLE COMPLETION

Installed 56' of 1" plastic pipe. Bottom 40' perforated. Pulled casing. Set capped 2½" steel pipe to 5' as surface protection. Backfilled at surface with cuttings.

PENETRATION TESTS

Probably not valid because of rocky nature of material See far right column on page 1.

WATER LEVELS

Depth	Date
29.7'	7-29-82
30.1'	8-3-82

EXPLANATION

** See page 1.

CORE LOSS
CORE RECOVERY

Type of hole . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Pattengail Creek Damsite PROJECT STATE Montana SHEET 2 OF 2 HOLE NO. DH82-4

7-1337 (6-74)
Water and Power

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Pattengall Creek Damsite PROJECT STATE Montana

HOLE NO. DH82-5 LOCATION Dam Station 17+00 15' Left GROUND ELEV. ** 1099.0'+ DIP (ANGLE FROM HORIZ.)

COORDS. N. E.

BEGUN 7-27-82 FINISHED 8-2-82 DEPTH OF OVERBURDEN TOTAL DEPTH 58.0' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

DRILL
Mobile B-50 truck-mounted.

DRILLER
Clarence Swanson (Montana Highway Department)

METHOD
Started first hole at site on 7-27-82. Abandoned after 10' because of large boulders. Started second hole on 7-28-82. 2 15/16" rockbit wash sample 0-5'. 2" split spoon drive 5-6.4'. 2 15/16" rockbit wash 6.4-10'. 2" split spoon drive 10-10.8'. 2 15/16" rockbit wash 10.8-20'. 2" split spoon drive 20-21.9'. 2 15/16" rockbit wash 21.9-53'. Ax diamond core 53-54'. 2 15/16" rockbit wash 54-58'. Driller had almost no recovery because of cobbles and boulders. Had to abandon hole after casing could not be driven past 24' to prevent caving. 2" split spoon drives and PR tests attempted numerous times but could not get through boulders and cobbles. Water used as drill fluid. Percolation tests taken where shown.

CASING RECORD
Set Nx casing in 5' lengths to 24'. Could not get past boulder. Pulled all casing on completion of hole.

Depth	Date
0-7'	7-27-82
Moved Hole	7-28-82
0-15'	7-28-82
15-24'	7-29-82

TYPE AND SIZE OF HOLE / CORE RECOVERY (%)

Type and size of hole	Core recovery (%)
Wash	0
2"	21
Wash	0
2"	75
Wash	0
2"	100
Wash	0
Ax	10
Wash	0

PERCOLATION TESTS

Depth (feet) From (P, Cs, or Cm)	To	Loss (G.P.M.)	Pressure (P.S.I.)	Length of test (Min.)
10 Cs	15	4.0	grav.	5
15 Cs	20	1.0	grav.	5
20 Cs	25	1.0	grav.	5
25 Cs	30	2.0	grav.	5

NOTE: Water loss about 1 gpm while drilling from 25 to 58'

ELEVATION (FEET): 1041.0 DEPTH (FEET): 58.0

CLASSIFICATION AND PHYSICAL CONDITION

NOTE: This drill hole was so rocky that very little recovery of core occurred. The log is based almost entirely on rockbit wash samples and the Driller's notes.

PLEISTOCENE - GLACIAL TILL

0-58.0' SILTY, SANDY GRAVEL: Not enough recovery to estimate percentages of composition. Material is composed mostly of sand and gravel with a large number of quartzite and igneous boulders. Low water losses indicate a significant quantity of silty fines, but not enough to prevent caving (maybe 15-20%). Material has no HCl reaction; is moist and loose to crumbly; and varies from tan to gray. (GM)?

PENETRATION TESTS

Depth	No. Blows Per Foot	Moisture Content%
5.5-5.8'	50/0.3'	6.2
10.5-10.7'	50/0.2'	5.3

NOTE: This hole should be redrilled if further exploration is warranted.

EXPLANATION

CORE LOSS

CORE RECOVERY

** All elevations are based on a reference bar with an assumed elevation. Actual elevation of top of dam is about 6320'+.

Type of hole . . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1 2", Ax = 1-7 8", Bx = 2-3 8", Nx = 3"
Approx. size of core (X-series) . Ex = 7 8", Ax = 1 1 8", Bx = 1 5 8", Nx = 2-1 8"
Outside dia. of casing (X series) Ex = 1-13 16", Ax = 2-1 4", Bx = 2-7 8", Nx = 3-1 2"
Inside dia. of casing (X series) Ex = 1-1 2", Ax = 1-29 32", Bx = 2 3 8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Pattengail Creek Damsite PROJECT STATE Montana

HOLE NO DH82-5 LOCATION Dam Station 17+00 15' Left GROUND ELEV. ** 1099.0'± DIP (ANGLE FROM HORIZ.)

COORDS. N. E.

BEGUN 7-27-82 FINISHED 8-2-82 DEPTH OF OVERBURDEN TOTAL DEPTH 58.0' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
PROGRESS RECORD Depth Date 0-10' 7-27-82 Abandoned 7-28-82 0-15' 7-28-82 15-25' 7-29-82 25-58' 8-2-82 HOLE COMPLETION Set 1" plastic pipe to 33'. Bottom 20' perforated. Pulled casing. Set capped 2½" steel pipe to 5' as surface protection. Backfilled at surface with cuttings. PENETRATION TESTS See far right column. Probably of not much validity because of rocks. WATER LEVELS Depth Date 13.7' 8-3-82 Probably not stable as of 8-3-82.												

EXPLANATION

** See page 1.

CORE LOSS

CORE RECOVERY

Type of hole . . . . D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature Pattengail Creek Damsite Project ______ Area Designation Borrow Area A

Hole No. TP82-101 Coordinates N. ______ E ______ Ground Elevation * 1200.0' Approx. Dimensions 10x4x6

Depth to Water Level* Dry Method of Excavation Backhoe Date 6-30-82 Logged by Parish

CLASSIFICATION SYMBOL LETTER	CLASSIFICATION SYMBOL GRAPHIC	DEPTH (FEET)	SIZE AND TYPE OF SAMPLE TAKEN	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE CHART - "UNIFIED SOIL CLASSIFICATION"; GIVE GEOLOGIC AND IN-PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	PERCENTAGE OF COBBLES AND BOULDERS ** VOLUME OF HOLE SAMPLED (CUBIC FEET)	WEIGHT OF 3 TO 5-INCH SAMPLED (LBS.)	PERCENTAGE BY VOLUME OF 3 TO 5-INCH***	WEIGHT OF PLUS 5-INCH SAMPLED (LBS.)	PERCENTAGE BY VOLUME OF PLUS 5-INCH***
ML		1.5	None	PLEISTOCENE - OUTWASH AND MORAINE DEPOSITS 0-1.5' SANDY SILT: approx. 75% nonplastic fines; 25% mostly fine sand; occasional subrounded quartzite gravels to 2"; moist; loose; pine roots to 1.5'; no HCl reaction; light brown. (ML)					
GP		6.0		1.5-6.0' SANDY GRAVEL: approx. 65% fine to coarse subrounded quartzite gravel to 3"; 35% fine to coarse sand; moist; loose; no HCl reaction; light brown. (GP)			5		5

REMARKS. Borrow Area A located in SE¼, Sec. 3, T. 2 S., R. 12 W. Maximum size boulders in 1.5 to 6.0' unit are approx. 14". Top 1.5' would have to be stripped to be rid of most pine roots.

*Elevation based on a reference point with an assumed elevation. Actual elevation of Borrow Area A is about 6320'±.

NOTES: Record water test and density test data, if applicable, under remarks.
* Record after water has reached its natural level; give date of reading adjacent to graphic symbol or in remarks.
** Applicable only to borrow pits and to foundations which are potential sources of construction materials.

*** $\frac{\text{(Lbs. of rock sampled) 100}}{\text{(Bulk specific gravity of rock) 62.4 (Cubic feet of hole sampled)}}$
Record bulk specific gravity in Remarks, stating how obtained (measured or estimated)

Pattengail Creek Damsite Borrow Area A TP82-10[illegible] GPO 844-814

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature Pattengail Creek Damsite Project ______ Area Designation Borrow Area A

Hole No. TP82-102 Coordinates N. ______ E ______ Ground Elevation * 1207.02' Approx. Dimensions 10x4x5

Depth to Water Level* Dry Method of Excavation Backhoe Date 6-30-82 Logged by Parish

CLASSIFICATION SYMBOL: LETTER	CLASSIFICATION SYMBOL: GRAPHIC	DEPTH (FEET)	SIZE AND TYPE OF SAMPLE TAKEN	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE CHART - "UNIFIED SOIL CLASSIFICATION"; GIVE GEOLOGIC AND IN-PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	PERCENTAGE OF COBBLES AND BOULDERS **: VOLUME OF HOLE SAMPLED (CUBIC FEET)	WEIGHT OF 3 TO 5-INCH SAMPLED (LBS)	PERCENTAGE BY VOLUME OF 3 TO 5-INCH***	WEIGHT OF PLUS 5-INCH SAMPLED (LBS)	PERCENTAGE BY VOLUME OF PLUS 5-INCH***
SM		2.5	None	PLEISTOCENE - OUTWASH AND MORAINE DEPOSITS 0-2.5' SILTY SAND: approx. 75% mostly fine sand; 10% subrounded quartzite gravel to 3"; 15% nonplastic fines; moist; loose; lots of tree roots; no HCl reaction; light brown. (SM)			less than 5		less than 5
GP		5.0		2.5-5.0' SANDY GRAVEL: approx. 65% fine to coarse subrounded quartzite gravel to 3"; 35% fine to coarse sand; moist; loose; no HCl reaction; light brown. (GP)			25		30

REMARKS:

Maximum sizes in the units are: 12" in top unit; 16" in bottom unit.
Most of top unit (1.5') would have to be stripped to be rid of most pine roots.
Borrow Area A located in SE¼, Sec. 3, T. 2 S., R. 12 W.

*Elevation based on a reference point with an assumed elevation. Actual elevation of Borrow Area A is about 6320'±.

NOTES: Record water test and density test data, if applicable, under remarks.
* Record after water has reached its natural level; give date of reading adjacent to graphic symbol or in remarks.
** Applicable only to borrow pits and to foundations which are potential sources of construction materials.

*** $\frac{(\text{Lbs of rock sampled})\,100}{(\text{Bulk specific gravity of rock})\,62.4\,(\text{Cubic feet of hole sampled})}$
Record bulk specific gravity in Remarks, stating how obtained (measured or estimated)

Pattengail Creek Damsite   Borrow Area A   TP82-102   GPO 844-814

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature Pattengail Creek Damsite Project ______ Area Designation Borrow Area A

Hole No. TP82-103 Coordinates N. ______ E ______ Ground Elevation 1216.65' * Approx. Dimensions 10x4x8

Depth to Water Level* Dry Method of Excavation Backhoe Date 6-30-82 Logged by Parish

CLASSIFICATION SYMBOL LETTER	GRAPHIC	DEPTH (FEET)	SIZE AND TYPE OF SAMPLE TAKEN	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE CHART - "UNIFIED SOIL CLASSIFICATION"; GIVE GEOLOGIC AND IN-PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	PERCENTAGE OF COBBLES AND BOULDERS ** VOLUME OF HOLE SAMPLED (CUBIC FEET)	WEIGHT OF 3 TO 5-INCH SAMPLED (LBS)	PERCENTAGE BY VOLUME OF 3 TO 5-INCH***	WEIGHT OF PLUS 5-INCH SAMPLED (LBS)	PERCENTAGE BY VOLUME OF PLUS 5-INCH***
ML		6.0	60 lb. Composite 1-6'	PLEISTOCENE - OUTWASH AND MORAINE DEPOSITS 0-6.0' SANDY SILT: approx. 55% nonplastic fines; 40% mostly fine sand; 5% subangular to subrounded quartzite gravel to 2"; a few cobbles to 8"; moist; crumbly; pine roots to 1.5'; no HCl reaction; brown. (ML)					
GP		8.0		6.0-8.0' GRAVEL: approx. 60% fine to coarse subrounded mostly quartzite to gravel to 3"; 35% fine to coarse sand; 5% nonplastic fines; moist; loose; no HCl reaction; brown. (GP)			5		5

REMARKS: Borrow Area A is located in SE¼, Sec. 3, T. 2 S., R. 12 W. Maximum size boulders in 6-8' unit are approx. 14". At least the top 1.5' of area would have to be stripped to get rid of tree roots.

* Elevation based on a reference point with an assumed elevation. Actual elevation of Borrow Area A is about 6320'±.

NOTES: Record water test and density test data, if applicable, under remarks.
* Record after water has reached its natural level; give date of reading adjacent to graphic symbol or in remarks.
** Applicable only to borrow pits and to foundations which are potential sources of construction materials.

*** $\frac{\text{(Lbs. of rock sampled) 100}}{\text{(Bulk specific gravity of rock) 62.4 (Cubic feet of hole sampled)}}$
Record bulk specific gravity in Remarks, stating how obtained (measured or estimated)

Pattengail Creek Damsite Borrow Area A TP82-103 GPO 844-814

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature Pattengail Creek Damsite Project ______ Area Designation Borrow Area A

Hole No. TP82-104 Coordinates N. ______ E ______ Ground Elevation 1221.89' * Approx. Dimensions 10x4x7

Depth to Water Level* Dry Method of Excavation Backhoe Date 6-30-82 Logged by Parish

Classification Symbol: Letter	Classification Symbol: Graphic	Depth (feet)	Size and type of sample taken	Classification and description of material (See chart - "Unified Soil Classification"; give geologic and in-place description for foundation investigations)	Percentage of cobbles and boulders **: Volume of hole sampled (cubic feet)	Weight of 3 to 5-inch sampled (lbs)	Percentage by volume of 3 to 5-inch ***	Weight of plus 5-inch sampled (lbs)	Percentage by volume of plus 5-inch ***
ML		0-5.0	60 lb. composite 1-5'	PLEISTOCENE - OUTWASH AND MORAINE DEPOSITS 0-5.0' SANDY SILT: approx. 55% nonplastic fines; 35% mostly fine sand; 10% subrounded mostly quartzite gravel to 2"; moist; crumbly; pine roots to 1.5'; no HCl reaction; light brown. (ML)					
SP-SM		5.0-7.0		5.0-7.0' SAND: approx. 90% mostly fine sand; 10% non-plastic fines; layered as if of lacustrine origin; moist; crumbly; no HCl reaction; light brown. (SP-SM) Note: Cobble layer at bottom of pit.					

REMARKS: Borrow Area A is located in SE¼, Sec. 3, T. 2 S., R. 12 W. At least top 1.5' of area will have to be stripped to get rid of tree roots.

* Elevation based on a reference point with an assumed elevation. Actual elevation of Borrow Area A is about 6320' ±.

NOTES: Record water test and density test data, if applicable, under remarks.
* Record after water has reached its natural level; give date of reading adjacent to graphic symbol or in remarks.
** Applicable only to borrow pits and to foundations which are potential sources of construction materials.
*** $\frac{\text{(Lbs. of rock sampled) } 100}{\text{(Bulk specific gravity of rock) } 62.4 \text{ (Cubic feet of hole sampled)}}$
Record bulk specific gravity in Remarks, stating how obtained (measured or estimated)

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature Pattengail Creek Damsite Project ______ Area Designation Borrow Area A

Hole No. TP82-105 Coordinates N. ______ E ______ Ground Elevation 1202.02' * Approx. Dimensions 10x4x6

Depth to Water Level Dry Method of Excavation Backhoe Date 6-30-82 Logged by Parish

Classification Symbol: Letter	Classification Symbol: Graphic	Depth (Feet)	Size and Type of Sample Taken	Classification and Description of Material (See chart - "Unified Soil Classification"; give geologic and in-place description for foundation investigations)	Volume of Hole Sampled (Cubic Feet)	Weight of 3 to 5-inch Sampled (Lbs.)	Percentage by Volume of 3 to 5-inch***	Weight of Plus 5-inch Sampled (Lbs.)	Percentage by Volume of Plus 5-inch***
				Percentage of Cobbles and Boulders **					
SM		5.0	60 lb. Composite 1-5'	PLEISTOCENE - OUTWASH AND MORAINE DEPOSITS 0-5.0' SILTY SAND: approx. 55% mostly fine sand; 45% nonplastic fines; scattered subrounded quartzite gravel to 2"; wet (slightly above OMC); crumbly; pine roots to 1.5'; no HCl reaction; brown. (SM)					
GP		6.0		5.0-6.0' GRAVEL: approx. 65% fine to coarse subrounded mostly quartzite gravel to 3"; 35% fine to coarse sand; trace of nonplastic fines; moist; loose; no HCl reaction; brown. (GP)			5		5

REMARKS: Borrow Area A is located in SE¼, Sec. 3, T. 2 S., R. 12 W. Maximum size boulders in 5-6' unit are approx. 16". At least the top 1.5' of the area will have to be stripped to get rid of tree roots.

* Elevation based on a reference point with an assumed elevation. Actual elevation of Borrow Area A is about 6320'±.

NOTES: Record water test and density test data, if applicable, under remarks.
* Record after water has reached its natural level; give date of reading adjacent to graphic symbol or in remarks.
** Applicable only to borrow pits and to foundations which are potential sources of construction materials.

*** $\frac{\text{(Lbs of rock sampled) } 100}{\text{(Bulk specific gravity of rock) } 62.4 \text{ (Cubic feet of hole sampled)}}$
Record bulk specific gravity in Remarks, stating how obtained (measured or estimated)

LOG OF TEST PIT OR AUGER HOLE

FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature Pattengail Creek Damsite Project ______ Area Designation Borrow Area A

Hole No. TP82-106 Coordinates N. ______ E ______ Ground Elevation 1209.84' * Approx. Dimensions 10x4x7

Depth to Water Level* Dry Method of Excavation Backhoe Date 6-30-82 Logged by Parish

CLASSIFICATION SYMBOL: LETTER	CLASSIFICATION SYMBOL: GRAPHIC	DEPTH (FEET)	SIZE AND TYPE OF SAMPLE TAKEN	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE CHART - "UNIFIED SOIL CLASSIFICATION"; GIVE GEOLOGIC AND IN-PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	PERCENTAGE OF COBBLES AND BOULDERS **: VOLUME OF HOLE SAMPLED (CUBIC FEET)	WEIGHT OF 3 TO 5-INCH SAMPLED (LBS)	PERCENTAGE BY VOLUME OF 3 TO 5-INCH***	WEIGHT OF PLUS 5-INCH SAMPLED (LBS)	PERCENTAGE BY VOLUME OF PLUS 5-INCH***
SC		7.0	60 lb. Composite 1-7'	PLEISTOCENE - OUTWASH AND MORAINE DEPOSITS 0-7.0' CLAYEY, GRAVELLY SAND: approx. 40% mostly fine sand; 25% fine to coarse, subrounded quartzite gravel to 3"; 35% very low plasticity fines; moist; crumbly; coarse pine roots to 1.5'; some fine roots to 5.0'; no HCl reaction; lenses of sand and clay; brown. (SC)					

REMARKS: Borrow Area A located in SE¼, Sec. 3, T. 2 S., R. 12 W. At least the top 1.5' of the area will have to be stripped to get rid of the tree roots.

* Elevation based on a reference point with an assumed elevation. Actual elevation of Borrow Area A is about 6320'±.

NOTES: Record water test and density test data, if applicable, under remarks.
* Record after water has reached its natural level; give date of reading adjacent to graphic symbol or in remarks.
** Applicable only to borrow pits and to foundations which are potential sources of construction materials.

$$*** \frac{\text{(Lbs. of rock sampled) } 100}{\text{(Bulk specific gravity of rock) } 62.4 \text{ (Cubic feet of hole sampled)}}$$

Record bulk specific gravity in Remarks, stating how obtained (measured or estimated)

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature Pattengail Creek Damsite Project ______ Area Designation Borrow Area A

Hole No. TP82-107 Coordinates N. ______ E ______ Ground Elevation * 1196.06' Approx. Dimensions 10x4x3

Depth to Water Level* Dry Method of Excavation Backhoe Date 6-30-82 Logged by Parish

CLASSIFICATION SYMBOL		DEPTH (FEET)	SIZE AND TYPE OF SAMPLE TAKEN	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE CHART - "UNIFIED SOIL CLASSIFICATION" GIVE GEOLOGIC AND IN-PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	PERCENTAGE OF COBBLES AND BOULDERS **				
LETTER	GRAPHIC				VOLUME OF HOLE SAMPLED (CUBIC FEET)	WEIGHT OF 3 TO 5-INCH SAMPLED (LBS)	PERCENTAGE BY VOLUME OF 3 TO 5-INCH***	WEIGHT OF PLUS 5-INCH SAMPLED (LBS)	PERCENTAGE BY VOLUME OF PLUS 5-INCH***
SC		3.0	None	PLEISTOCENE - OUTWASH AND MORAINE DEPOSITS 0-3.0' CLAYEY SAND: approx. 60% mostly fine sand; 40% low plasticity fines; scattered subrounded quartzite gravel to 3"; moist; crumbly; pine roots throughout the unit; no HCl reaction; light brown. (SC) Note: Pit stopped by cobbles and boulders at 3.0'.					

REMARKS:

Top 1.5' of unit would have to be stripped to get rid of most pine roots.

Borrow Area A located in SE¼, Sec. 3, T. 2 S., R. 12 W.

* Elevation based on a reference point with an assumed elevation. Actual elevation of Borrow Area A is about 6320.+.

NOTES: Record water test and density test data, if applicable, under remarks.
* Record after water has reached its natural level; give date of reading adjacent to graphic symbol or in remarks.
** Applicable only to borrow pits and to foundations which are potential sources of construction materials.

*** $\frac{(\text{Lbs. of rock sampled})\ 100}{(\text{Bulk specific gravity of rock})\ 62.4\ (\text{Cubic feet of hole sampled})}$
Record bulk specific gravity in Remarks, stating how obtained (measured or estimated)

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature: Pattengail Creek Damsite Project: ____ Area Designation: Borrow Area A

Hole No.: TP32-108 Coordinates N. ____ E ____ Ground Elevation: * 1213.82' Approx. Dimensions: 10x4x1.5

Depth to Water Level*: Dry Method of Excavation: Backhoe Date: 6-30-82 Logged by: Parish

CLASSIFICATION SYMBOL		DEPTH (FEET)	SIZE AND TYPE OF SAMPLE TAKEN	CLASSIFICATION AND DESCRIPTION OF MATERIAL (SEE CHART - "UNIFIED SOIL CLASSIFICATION"; GIVE GEOLOGIC AND IN-PLACE DESCRIPTION FOR FOUNDATION INVESTIGATIONS)	PERCENTAGE OF COBBLES AND BOULDERS **				
LETTER	GRAPHIC				VOLUME OF HOLE SAMPLED (CUBIC FEET)	WEIGHT OF 3 TO 5-INCH SAMPLED (LBS.)	PERCENTAGE BY VOLUME OF 3 TO 5-INCH***	WEIGHT OF PLUS 5-INCH SAMPLED (LBS.)	PERCENTAGE BY VOLUME OF PLUS 5-INCH***
SC		1.5	None	PLEISTOCENE - OUTWASH AND MORAINE DEPOSITS 0-1.5' CLAYEY SAND: approx. 65% mostly fine sand; 35% very low plasticity fines; moist; crumbly; pine roots throughout unit, no HCl reaction; brown. (SC) Note: Pit stopped by cobbles and boulders at 1.5'.					

REMARKS:

The whole unit would have to be stripped to get rid of tree roots.

Borrow Area A located in SE¼, Sec. 3, T. 2 S., R. 12 W.

*Elevation based on a reference point with an assumed elevation. Actual elevation of Borrow Area A is about 6320'±.

NOTES: Record water test and density test data, if applicable, under remarks.
* Record after water has reached its natural level; give date of reading adjacent to graphic symbol or in remarks.
** Applicable only to borrow pits and to foundations which are potential sources of construction materials.

*** $\frac{\text{(Lbs. of rock sampled) } 100}{\text{(Bulk specific gravity of rock) } 62.4 \text{ (Cubic feet of hole sampled)}}$
Record bulk specific gravity in Remarks, stating how obtained (measured or estimated)

Pattengail Creek Damsite Borrow Area A TP32-108 GPO 844-814

DEPARTMENT OF HIGHWAYS

TED SCHWINDEN, GOVERNOR

2701 PROSPECT

STATE OF MONTANA

HELENA, MONTANA 59620

August 18, 1982

Pattengail Creek Dam Site
AR. Act. No. 0040-0161-5018
Lag Nos. 553054-553062

Department of Natural Resources
& Conservation
Water Development
32 South Ewing
Helena, MT 59601

Attention: Mr. Mike Rubich

Gentlemen:

Attached are the results of laboratory testing of soil samples submitted for the above referenced project. Testing was accomplished in accordance with AASHTO or ASTM procedures.

If you have any further questions, please contact us at your convenience.

Sincerely,

Richard E. Wegner

Richard E. Wegner, P.E.
Chief - Materials Bureau

REW:TLY:cp:3N

Attachments

STATE OF MONTANA HIGHWAY COMMISSION

Soil Mechanics Test Report

Project No. CO40-161-5018 Project Designation PATTENGAIL CK. DAM SITE

County BEAVERHEAD Type Sample DISTURBED Submitted BY DNRC

Date Submitted Tested BY MPC Date Tested 8-82

Lab. No.	T.H.No.	(FT.) Depth	#/ft.³	%H_2O	PSF Swell	Remarks	Gradation % Pass 10	20	40	60	140	200	Limits LL	PL	PI	Soil Class
553054	82-103	1'-6										56.2	20	19	1	A-4(2)
553055	82-104	1'-5'										53.6	22	18	4	A-4(2)
553056	82-105	1'-5'										46.0	21	18	3	A-4(1)
553057	82-106	1'-7'										30.6	21	13	8	A-2-4
553058	82-1	45.5-46.5		36.1												
	"	50.5-51.5		26.5												
	"	55.5-56.5		39.5												
	"	60.5-61.5		27.9												
	"	65.5-66.5		27.2												
	"	70.5-71.5		26.1												
	"	75.5-76.5		20.9												
	"	80.5-81.5		19.9												
	"	85.5-86.5		24.1												
	"	90.5-91.5		21.6												
	"	95.5-96.5		20.5												
	"	100.5-101.5		22.0												

STATE OF MONTANA HIGHWAY COMMISSION

Soil Mechanics Test Report

Project No. 0040-161-5018 Project Designation PATTENGAIL CK. DAM SITE

County BEAVERHEAD Type Sample DISTURBED Submitted BY DNRC

Date Submitted Tested BY MPC Date Tested 8-82

Lab. No.	T.H.No.	Depth	#/ft.^{3}	%H_2O	PSF Swell	Remarks	Gradation % Pass						Limits			Soil Class
							10	20	40	60	140	200	LL	PL	PI	
	82-1	105.5-106.5		25.2												
	"	110.5-111.5		16.5												
553059	82-2	15.5-13.5		12.9												
	"	15.5-16.5		6.0												
	"	20.5-21.5		19.1												
	"	25.5-26.5		12.7												
	"	30.5-31.5		10.2												
	"	35.5-36.5		6.5												
	"	40.5-40.9		5.5												
553060	82-3	5.5-6.3		3.9												
	"	10.5-11.2		4.4												
	"	20.5-21.5		6.4												
	"	25.5-26.5		7.7												
	"	30.5-31.5		14.5												
	"	35.5-36.5		17.5												
	"	40.5-41.5		6.3												

STATE OF MONTANA HIGHWAY COMMISSION

Soil Mechanics Test Report

Project No. 0040-161-5018 Project Designation PATTENGAIL CK. DAM SITE

County BEAVERHEAD Type Sample DISTURBED Submitted BY DNRC

Date Submitted Tested BY MPC Date Tested 8-82

Lab. No.	T.H.No.	Depth	$\#/ft.^3$	$\%H_2O$	PSF Swell	Remarks	Gradation % Pass						Limits			Soil Clas
							10	20	40	60	140	200	LL	PL	PI	
	82-3	50.5-51.5		7.0												
	"	60.5-61.2		7.7												
	"	70.0-71.2		6.2												
	"	80.5-80.6		8.9												
	"	85.5-85.8		6.2												
553061	82-4	5.5-6.5		3.1												
	"	10.5-11.5		4.5												
	"	20.5-21.0		6.0												
	"	25.5-26.2		5.8												
	"	35.5-35.9		6.6												
	"	40.5-41.3		7.5												
	"	46.0-46.5		7.4												
	"	50.5-50.7		5.6												
553062	82 5	5.5-5.8		6.2												
	"	10.5-10.7		5.3												

ab. Form 123
ev. 2-78

STATE OF MONTANA
DEPARTMENT OF HIGHWAYS
Helena, Montana

iv. Lab. No. ______

b. No. 553054 Sample TP Hole 82-103 Project 0040-161-5018
ermini PATTENGAIL CREEK DAM SITE 1-6'

ate Sampled ______ Date Received 8-82 Kind of Deposit ______
ampled By ______ Title ______ Address ______
ubmitted By ______ Title ______ Date ______
uantity ______ Area by Stationing ______
rea is in ______
ab No. ______ County ______
wner ______ Address ______
ta. and or Tons Production Sample ______ Lift No. ______
xamined For ______

t. of Sample Taken ______ lbs. 100.00 %
t. Retained 4-Mesh ______ lbs. ______ %
t. Passing 4-Mesh ______ lbs. ______ %
efore Wash ______ After Wash ______ LBW ______

nd.Wt.Ret.	Size	Tot.Wt.Pass.	Pct.	Spec.
	4½"		% PASSING	
	4"			
	3½"			
	3"			
	2½"			
	2"		100	
	1½"		99	
	1¼"		99	
	1"		98	
	⅞" ¾"		96	
	½"		95	
	⅜"		95	
	4M		94	
	10M		93	
	40M		88	
	80M		75	
	200M		56.2	

LL ______ PL ______ PI ______
Wear ______ % Fracture ______ %
Dust Ratio ______ Sand Equivalent ______
Soil Class ______ Sp.Gr.(F) ______ (C) ______
Max. Dens. ______ Opt. Moist. ______
Fld.Agg.Chart No. ______ Div.Lab.No. ______
Comp.Wt.Bit.Mix(.1' Thick) ______ lbs/yd^2
Est. Compacted Wt. Agg. ______ lbs/yd^3

VOLUME SWELL				
Age	Treatment	% Swell	Spec.	Specimen Condition

% Adhesion	Bitumen	Adhesive Agent

CHECKED AND APPROVED	DATE	NAME

EMARKS:

MATERIALS BUREAU DISTR.
___ Div. Const. Sect. ______
___ Div. Materials ______
___ Surf. Design Unit-Helena
___ ______ County File
___ ______
___ Materials Bureau File

DIV. DISTR.
___ Mat'ls Bureau
___ S.D.C.S.
___ M.F.P.U.
___ ______
___ Div. Lab. File
___ Sample

~~MATERIALS BUREAU~~
DATED ______

Lab. Form 123
Rev. 2-78

STATE OF MONTANA
DEPARTMENT OF HIGHWAYS
Helena, Montana

Div. Lab. No. ______

Lab. No. 553055 Sample TP Hole 82-104 Project 0040-161-5018
Termini PATTENGAIL CREEK DAM SITE 1'-5'

Date Sampled ______ Date Received 8-82 Kind of Deposit ______
Sampled By ______ Title ______ Address ______
Submitted By ______ Title ______ Date ______
Quantity ______ Area by Stationing ______
Area is in ______
Lab No. ______ County ______
Owner ______ Address ______
Sta. and or Tons Production Sample ______ Lift No. ______
Examined For ______

Wt. of Sample Taken ______ lbs. 100.00 %
Wt. Retained 4-Mesh ______ lbs. ______ %
Wt. Passing 4-Mesh ______ lbs. ______ %
Before Wash ______ After Wash ______ LBW ______

Ind.Wt.Ret.	Size	Tot.Wt.Pass.	Pct.	Spec.
	4½"		% PASSING	
	4"			
	3½"			
	3"			
	2½"			
	2"		100	
	1½"		99	
	1¼"		99	
	1"		98	
	5/8 3/4"		96	
	½"		94	
	3/8"		93	
	4M		92	
	10M		91	
	40M		86	
	80M		73	
	200M		53.6	

LL ______ PL ______ PI ______
Wear ______ % Fracture ______ %
Dust Ratio ______ Sand Equivalent ______
Soil Class ______ Sp.Gr.(F) ______ (C) ______
Max. Dens. ______ Opt. Moist. ______
Fld.Agg.Chart No. ______ Div.Lab.No. ______
Comp.Wt.Bit.Mix(.1' Thick) ______ lbs/yd^2
Est. Compacted Wt. Agg. ______ lbs/yd^3

VOLUME SWELL

Age	Treatment	% Swell	Spec.	Specimen Condition

% Adhesion	Bitumen	Adhesive Agent

CHECKED AND APPROVED	DATE	NAME

REMARKS:

MATERIALS BUREAU DISTR.
__ Div. Const. Sect. ______
__ Div. Materials ______
__ Surf. Design Unit-Helena
__ ______ County File
__ ______
__ Materials Bureau File

DIV. DISTR.
__ Mat'ls Bureau
__ S.D.C.S.
__ M.F.P.U.
__ ______
__ Div. Lab. File
__ Sample

~~MATERIALS BUREAU~~
DATED ______

ab. Form 123
:ev. 2-78

STATE OF MONTANA
DEPARTMENT OF HIGHWAYS
Helena, Montana

)iv. Lab. No. ______

.ab. No. 553056 Sample TP Hole 82-105 Project 0040-161-5018
ermini PATTENGAIL CREEK DAM SITE 1-5'

)ate Sampled ______ Date Received 8-82 Kind of Deposit ______
ampled By ______ Title ______ Address ______
ubmitted By ______ Title ______ Date ______
)uantity ______ Area by Stationing ______
rea is in ______
.ab No. ______ County ______
)wner ______ Address ______
ta. and or Tons Production Sample ______ Lift No. ______
xamined For ______

It. of Sample Taken ______ lbs. 100.00 %
It. Retained 4-Mesh ______ lbs. ______ %
It. Passing 4-Mesh ______ lbs. ______ %
efore Wash ______ After Wash ______ LBW ______

nd.Wt.Ret.	Size	Tot.Wt.Pass.	Pct.	Spec.
	4½"		% PASSING	
	4"			
	3½"			
	3"			
	2½"			
	2"			
	1½"			
	1¼"			
	1"			
	⅝" ¾"			
	½"			
	⅜"			
TRACE	4M			
	10M		99	
	40M		88	
	80M		73	
	200M		46.0	

LL ______ PL ______ PI ______
Wear ______ % Fracture ______ %
Dust Ratio ______ Sand Equivalent ______
Soil Class ______ Sp.Gr.(F) ______ (C) ______
Max. Dens. ______ Opt. Moist. ______
Fld.Agg.Chart No. ______ Div.Lab.No. ______
Comp.Wt.Bit.Mix(.1' Thick) ______ lbs/yd²
Est. Compacted Wt. Agg. ______ lbs/yd³

VOLUME SWELL

Age	Treatment	% Swell	Spec.	Specimen Condition

% Adhesion	Bitumen	Adhesive Agent

CHECKED AND APPROVED	DATE	NAME

EMARKS:

ATERIALS BUREAU DISTR.
__ Div. Const. Sect. ______
__ Div. Materials ______
Surf. Design Unit-Helena
__ ______ County File
__ ______
__ Materials Bureau File

DIV. DISTR.
__ Nat'ls Bureau
__ S.D.C.S.
__ M.F.P.U.
__ ______
__ Div. Lab. File
__ Sample

MATERIALS BUREAU
DATED ______

ab. Form 123
ev. 2-78

STATE OF MONTANA
DEPARTMENT OF HIGHWAYS
Helena, Montana

iv. Lab. No. ______
b. No. 553057 Sample TP Hole 82-106 Project ______
ermini PATTENGAIL CREEK DAM SITE 1-7'

ate Sampled ______ Date Received 8-82 Kind of Deposit ______
ampled By ______ Title ______ Address ______
ubmitted By ______ Title ______ Date ______
uantity ______ Area by Stationing ______
rea is in ______
ab No. ______ County ______
wner ______ Address ______
ta. and or Tons Production Sample ______ Lift No. ______
xamined For ______

t. of Sample Taken ______ lbs. 100.00 %
t. Retained 4-Mesh ______ lbs. ______ %
t. Passing 4-Mesh ______ lbs. ______ %
efore Wash ______ After Wash ______ LBW ______

nd.Wt.Ret.	Size	Tot.Wt.Pass.	Pct.	Spec.
	4½"		% PASSING	
	4"			
	3½"		100	
	3"		98	
	2½"		96	
	2"		90	
	1½"		85	
	1¼"		81	
	1"		76	
	⅞ ¾"		72	
	½"		67	
	⅜"		65	
	4M		63	
	10M		61	
	40M		57	
	80M		48	
	200M		30.6	

LL ______ PL ______ PI ______
Wear ______ % Fracture ______ %
Dust Ratio ______ Sand Equivalent ______
Soil Class ______ Sp.Gr.(F) ______ (C) ______
Max. Dens. ______ Opt. Moist. ______
Fld.Agg.Chart No. ______ Div.Lab.No. ______
Comp.Wt.Bit.Mix(.1' Thick) ______ lbs/yd^2
Est. Compacted Wt. Agg. ______ lbs/yd^3

VOLUME SWELL				
Age	Treatment	% Swell	Spec.	Specimen Condition

% Adhesion	Bitumen	Adhesive Agent

CHECKED AND APPROVED	DATE	NAME

EMARKS:

IATERIALS BUREAU DISTR.
___ Div. Const. Sect. ______
___ Div. Materials ______
___ Surf. Design Unit-Helena
___ ______ County File
___ Materials Bureau File

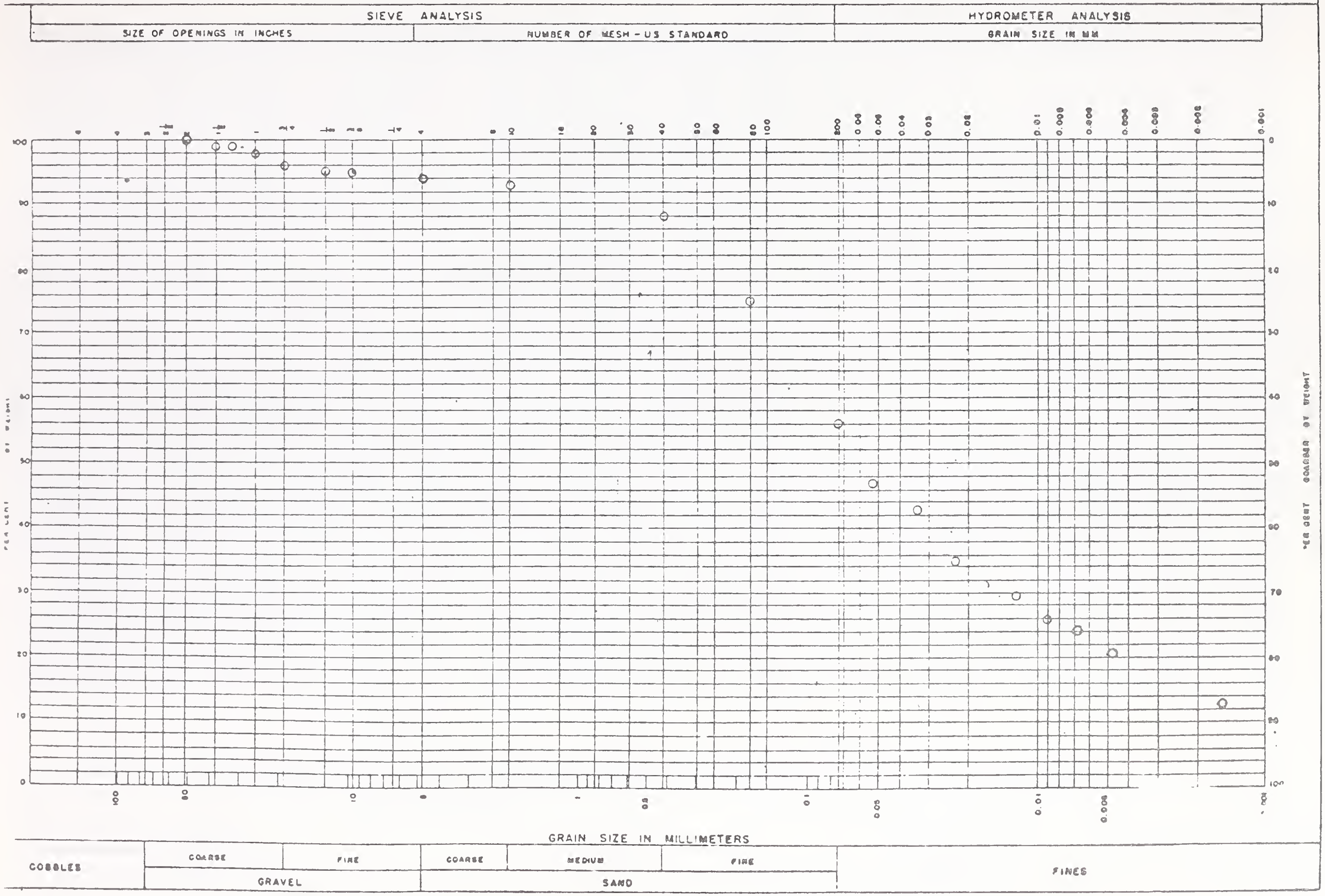
DIV. DISTR.
___ Mat'ls Bureau
___ S.D.C.S.
___ M.F.P.U.
___ ______
___ Div. Lab. File
___ Sample

~~MATERIALS BUREAU~~
DATED ______

MONTANA STATE ~~UNIVERSITY~~ DOH
~~DEPARTMENT OF CIVIL ENGINEERING~~
SOIL MECHANICS LABORATORY

GRADATION CURVE

PATTENGAIL CK.
BY DAM SITE LABORATORY NO 553054
DATE 8-82 FIELD NO. TP 82-103

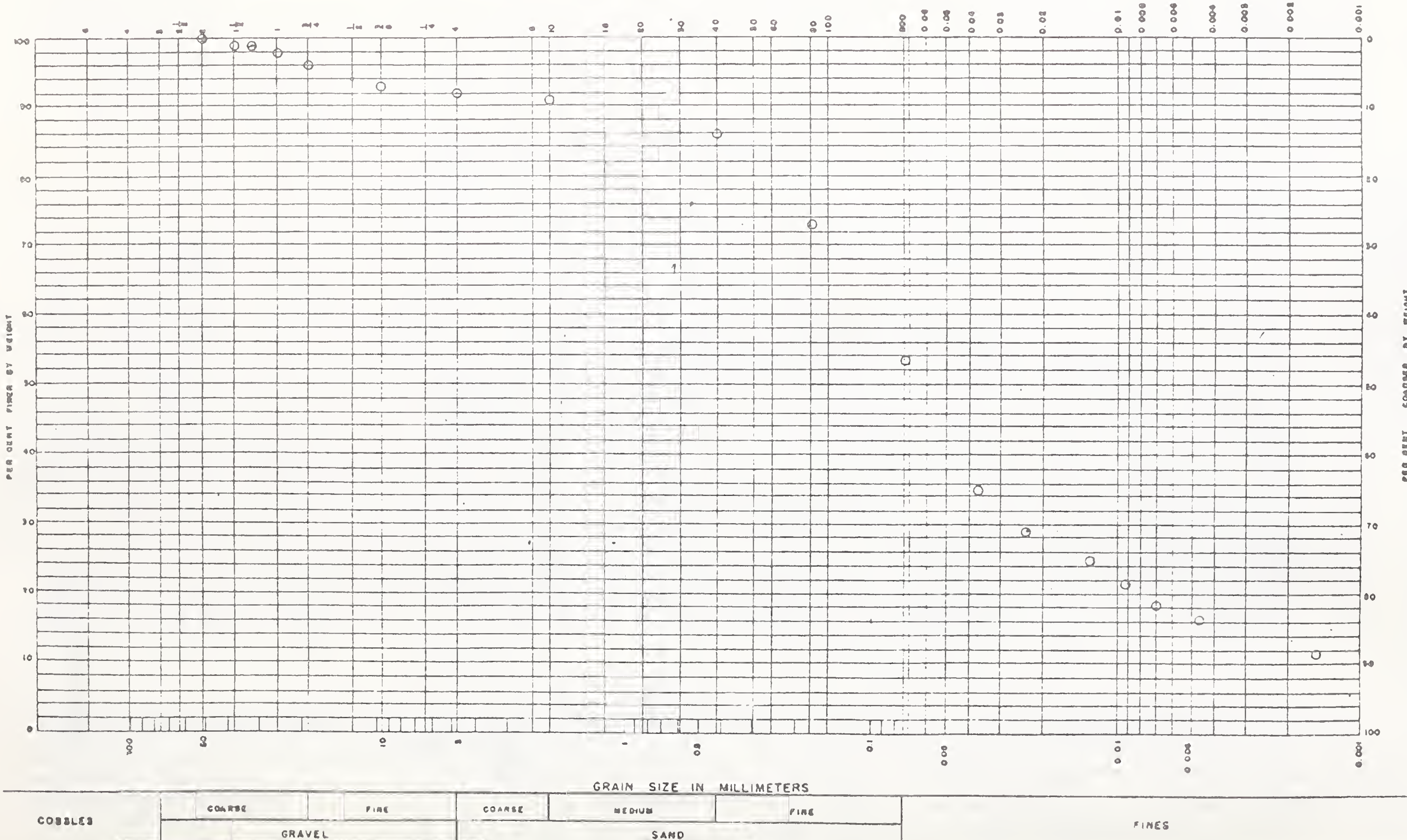


MONTANA STATE ~~UNIVERSITY~~ 004
~~DEPARTMENT OF CIVIL ENGINEERING~~
SOIL MECHANICS LABORATORY

GRADATION CURVE

PATTENGAIL CR.
BY DAM SITE LABORATORY NO. 553055
DATE 8-82 FIELD NO. TP 82-104

SIEVE ANALYSIS		HYDROMETER ANALYSIS
SIZE OF OPENINGS IN INCHES	NUMBER OF MESH - US STANDARD	GRAIN SIZE IN MM

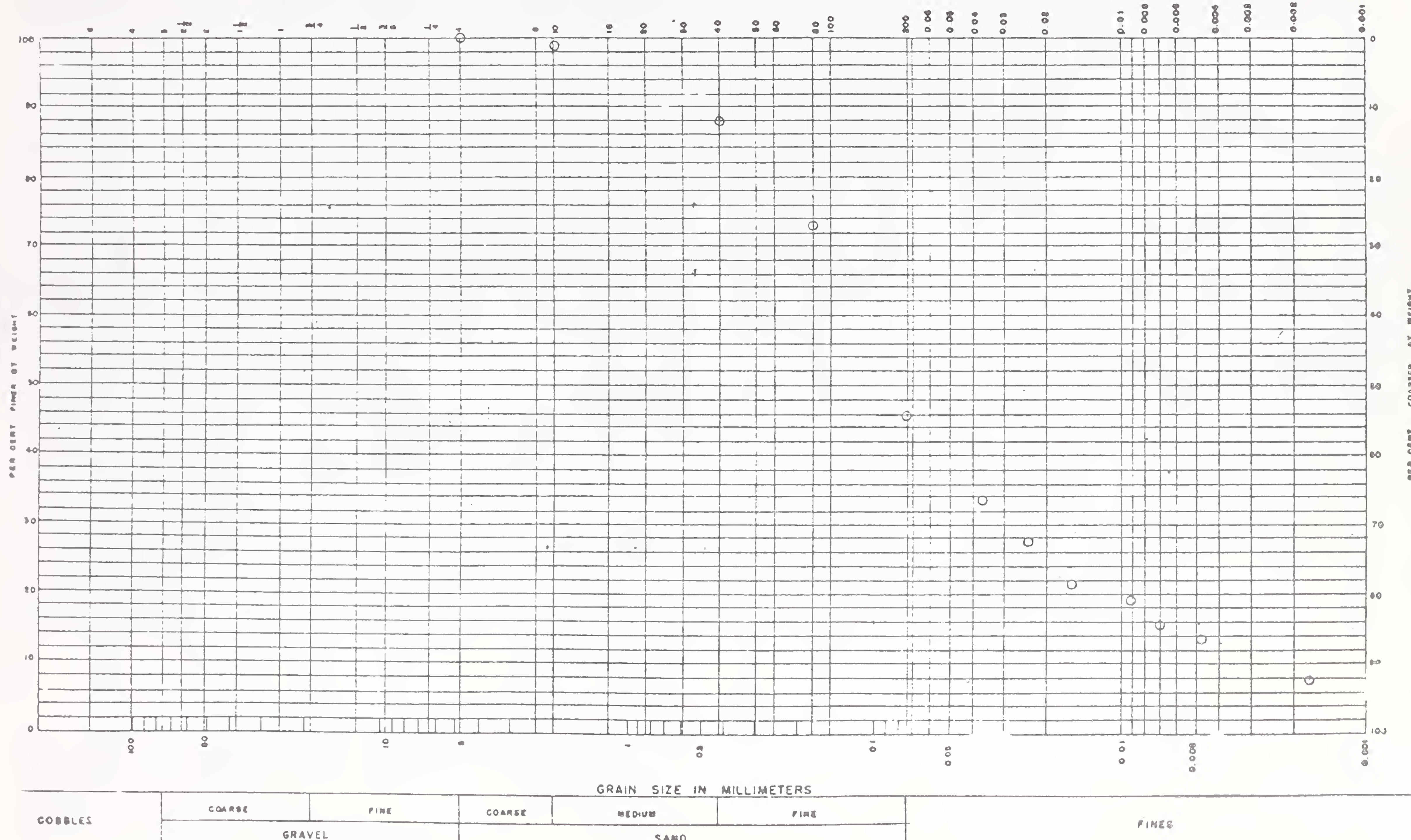


MONTANA STATE ~~UNIVERSITY~~ 004
~~DEPARTMENT OF CIVIL ENGINEERING~~
SOIL MECHANICS LABORATORY

GRADATION CURVE

PATTENGAIL CR.
BY DAM SITE LABORATORY NO 553056
DATE 8-82 FIELD NO. TP 82-105

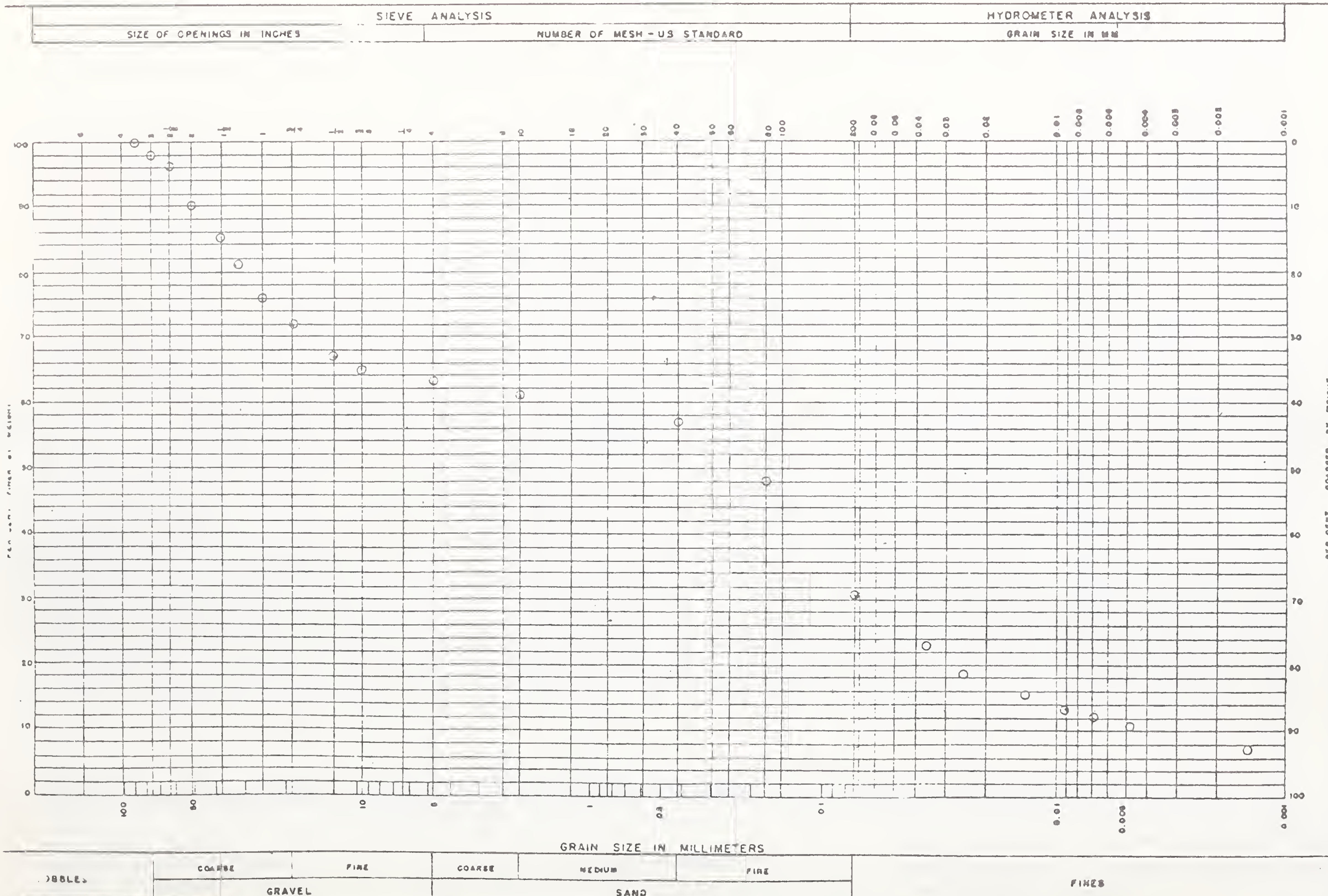
SIEVE ANALYSIS		HYDROMETER ANALYSIS
SIZE OF OPENINGS IN INCHES	NUMBER OF MESH - US STANDARD	GRAIN SIZE IN MM



MONTANA STATE ~~UNIVERSITY~~ DOH
~~DEPARTMENT OF CIVIL ENGINEERING~~
SOIL MECHANICS LABORATORY

GRADATION CURVE

PATTENGAIL CR.
BY DAM SITE LABORATORY NO 553057
DATE 8-82 FIELD NO. TP82-106



Appendix B

Economic Study Data

Agriculture: Benefits and Costs

The source for crop budgets in Chapter 4 was the Montana Cooperative Extension Service publication, "Cost of Irrigated Crop Production in the Sheridan and Twin Bridges Area of Madison County" (Shaefer, Griffith and Luft 1978). This budget was updated to 1982 prices, which were modified to represent higher yields and fertilization rates and to include a sprinkler irrigation system (see tables A, B, and C). These cost of production figures represent an above average level of management. In the original budget, no management cost was included; however, in the updated budgets, a management charge equal to 7 percent of gross receipts was included.

Gross receipts are a function of price and yield. In this study, average hay prices were assumed to be $60 per ton. Average yields for hay (assumed to be alfalfa-grass hay) were estimated from hay yields for southwestern Montana and from consultation with soil scientists at Montana State University.

The major assumptions used in the crop budgets are listed below:

1. The baseline yield, 2.2 tons per acre, was based on information collected in the 1981 Department of Natural Resources and Conservation (DNRC) study in the lower Big Hole Basin. The yields assumed under the project were 2.8 tons per acre (the average yield for alfalfa hay in southwestern Montana) under flood irrigated hay and increased fertilization rates, and 4.0 tons per acre under sprinkler irrigation and increased fertilization rates.

2. Land was valued at $600 per acre.

3. Establishment costs include planting and tearing out of alfalfa. These costs are amortized over ten years using an interest rate of 10 percent.

4. Costs computed for machines were based on average rather than new values.

5. An irrigation water charge of $5 per acre was included. (While this is not a water charge per se, it is the cost of maintaining ditches, gates, etc., for the delivery of the water.)

6. Electrical power rates to irrigators were calculated as if the 63 percent rate increase recommended by the Montana Public Service Commission were in effect.

7. The sprinkler system used in table C is a side roll, wheel-move system with a buried mainline. The fixed and variable costs associated with this system are outlined as follows:

	$/Acre/Year
Fixed costs:	
Depreciation	$20
Interest	25
Insurance	1
Total fixed costs	**$46**
Variable costs:	
Maintenance	$ 2
Electricity	19
Water	5
Labor	3
Total variable costs	**$29**

Sprinkler irrigaton costs were taken from a Montana Cooperative Extension Service publication entitled "Economics of Sprinkler Irrigation." All of the cost information was updated according to Agricultural Prices (USDA 1978 and 1982).

Table A. Per acre costs and returns of producing flood irrigated alfalfa-grass hay, baseline budget.

Description	Baseline Unit	Cost/Unit	Quantity	Total
Gross returns from production				
Alfalfa-grass hay	ton	$60.00	2.20	$132.00
Total gross returns				$132.00
Variable costs				
Nitrogen	lbs.	.25	32.00	8.00
Phosphate	lbs.	.20	40.00	8.00
Irrigation labor	hrs.	4.42	2.25	9.95
Machinery: fuel, oil, repairs	acre	17.88	1.00	17.88
Pickup v.c.	mile	.20	30.00	6.00
Miscellaneous expense	acre	8.14	1.00	8.14
Machinery labor	hour	4.42	1.52	6.72
Management	acre	9.24	1.00	9.24
Interest on operating capital	$	.19	10.53	2.00
Total variable cost				$ 75.92
Return over variable cost				$ 56.08
Breakeven price, based on variable costs				$ 34.51
Breakeven yield, based on variable costs				$ 1.27
Fixed costs				
Irrigation water	acre	5.00	1.00	$ 5.00
Machinery and tractors	acre	34.13	1.00	34.13
Taxes (land and improvements)	acre	4.49	1.00	4.49
Interest, insurance, and depreciation (land and improvements)	acre	.08	600.00	47.40
Pro-rated establishment costs	acre	9.98	1.00	9.98
Total fixed costs				$101.00
Total costs				$176.92
Net returns				-44.92
Breakeven price, based on total costs				$ 80.42
Breakeven yield, based on total costs				$ 2.95

Table B. Per acre costs and returns of producing flood irrigated alfalfa-grass hay, assuming the project is built.

Description	-----------With project---------			
	Unit	Cost/Unit	Quantity	Total
Gross returns from production				
Alfalfa-grass hay	ton	$60.00	2.80	$168.00
Total gross returns				$168.00
Variable costs				
Nitrogen	lbs.	.25	32.00	8.00
Phosphate	lbs.	.20	60.00	12.00
Irrigation labor	hrs.	4.42	2.25	9.95
Machinery: fuel, oil, repairs	acre	21.46	1.00	21.46
Pickup v.c.	mile	.20	30.00	6.00
Miscellaneous expense	acre	9.77	1.00	9.77
Machinery labor	hour	4.42	1.82	8.06
Management	acre	11.76	1.00	11.76
Interest on operating capital	$	.19	12.84	2.44
Total variable cost				$ 89.44
Return over variable cost				$ 78.56
Breakeven price, based on variable costs				$ 31.94
Breakeven yield, based on variable costs				$ 1.49
Fixed costs				
Irrigation water	acre	5.00	1.00	$ 5.00
Machinery and tractors	acre	34.13	1.00	34.13
Taxes (land and improvements)	acre	4.49	1.00	4.49
Interest, insurance, and depreciation (land and improvements)	acre	.08	600.00	47.40
Pro-rated establishment costs	acre	9.98	1.00	9.98
Total fixed costs				$101.00
Total costs				$190.44
Net returns				-22.44
Breakeven price, based on total costs				$ 68.01
Breakeven yield, based on total costs				$ 3.17

Table C. Per acre costs and returns of producing sprinkler irrigated alfalfa-grass hay, assuming the project is built.

Description	With project			
	Unit	Cost/Unit	Quantity	Total
Gross returns from production				
Alfalfa-grass hay	ton	$60.00	4.00	$240.00
Total gross returns				$240.00
Variable costs				
Nitrogen	lbs.	.25	32.00	8.00
Phosphate	lbs.	.20	60.00	12.00
Irrigation labor	hrs.	4.42	.64	2.83
Machinery: fuel, oil, repairs	acre	26.83	1.00	26.83
Pickup v.c.	mile	.20	30.00	6.00
Miscellaneous expense	acre	12.21	1.00	12.21
Machinery labor	hour	4.42	2.28	10.07
Irrigation maintenance and elec.	acre	20.75	1.00	20.75
Management	acre	16.80	1.00	16.80
Interest on operating capital	$	.19	16.00	3.04
Total variable cost				**$118.53**
Return over variable cost				**$121.47**
Breakeven price, based on variable costs				$ 29.63
Breakeven yield, based on variable costs				$ 1.98
Fixed costs				
Irrigation water	acre	5.00	1.00	$ 5.00
Machinery and tractors	acre	34.13	1.00	34.13
Taxes (land and improvements)	acre	4.49	1.00	4.49
Interest, insurance, and depreciation (land and improvements)	acre	.08	600.00	47.40
Irrigation (dep., int., and ins.)	acre	46.66	1.00	46.66
Pro-rated establishment costs	acre	9.98	1.00	9.98
Total fixed costs				**$147.66**
Total costs				**$266.19**
Net returns				-26.19
Breakeven price, based on total costs				$ 66.55
Breakeven yield, based on total costs				$ 4.44

Recreation: Benefits and Costs

The cost-benefit analysis of recreation (Chapter IV) was based on data from the Montana Department of Fish, Wildlife and Parks (DFWP), a master's thesis by Vincent Kozakiewicz, studies conducted by North Texas State University, and a study by Dr. Ronald Sutherland on the Flathead River and Lake system. A majority of the data is presented in Chapter IV; however, a few assumptions and procedures warrant additional attention.

The study area included 10 percent of Pattengail Creek, 40 percent of the Wise River, 100 percent of Reach 1 of the Big Hole River, and 30 percent of Reach 2 of the Big Hole River. These figures assumed that fishing and boating pressure was evenly distributed along the stream.

The fishing season extends from opening day -- the third Saturday in May -- until closing day, November 30. Ninety percent of all fishing and boating occurs from opening day through the weekend after Labor Day. The distribution of fisherman and boating days was based on fisherman hours collected in the Kozakiewicz study. Since this study only covered the fishing season from opening day through the weekend after Labor Day, it was assumed that 90 percent of the total fishing activity occurred in this time period.

Recreational boating activity was based on the relationship between boaters and fisherman indicated in a study of bank and floating fishermen on the upper Madison River (North Texas State University 1981). Based on a suggestion from the local DFWP biologist and a recreation specialist for DNRC, the upper Madison data were used as information representative of the relationship between fisherman and recreational boating activity in the Big Hole drainage -- i.e., one recreational boater was assumed for every 25 fishermen.

After computing the static value of the fishing and boating, a method was derived to correlate fishing and boating activity with increases in the instream flow. This was accomplished by using a data set that correlated minimum August flows with brown trout, age four and older, on the Big Hole River. The data set used, provided by Fred Nelson and Jerry Wells, DFWP fisheries biologists, is shown in table D.

Table D. Minimum August flows (cfs) and estimated standing crops of age IV+ and older brown trout in the Melrose study section of the Big Hole River.

Year	Minimum August Flow (cfs)	Brown Trout	Pounds
1969	230	584	--
1970	248	529	--
1977	174	498	1,132
1978	479	729	1,591
1979	256	517	1,218
1980	376	639	1,287

Source: Montana Department of Fish, Wildlife and Parks.

The regression equation gave a slightly better fit in correlating flows to number, rather than pounds, of fish. The equation is as follows:

$$y = 364.7 + .74\ x \quad (R^2=.8898)$$

where: x = flow, measured in cfs
y = number of fish

By using the number of fish as a proxy for the number of fishermen, a method for estimating fishing and boating activity at various rates of instream flow was found.

The short time frame of this study required the use of secondary data to establish a reasonable value for fisherman and boating days. After reviewing several secondary data sources, including work in Wyoming, Colorado, Washington, Oregon, and Montana, a study by Dr. Ronald Sutherland -- "Recreation and Preservation Valuation Estimates for Flathead River and Lake System" -- was chosen. In this study, "willingness to pay" was estimated by using the contingent valuation method. Values for fishing and boating were computed to be \$5.93 and \$11.23 per visitor day, respectively. Values used in other studies vary from \$0.26 to over \$20.00 per day.

Using actual expenditures as a proxy for "willingness to pay," the State of Wyoming estimated the value of a fisherman day to be \$24.87 (State of Wyoming 1980). In a study of the Kootenai Falls, Duffield estimated the maximum that people were willing to pay was \$2.36 per day (DNRC 1982). In a study of the Cooper Creek area of Oregon, the value of a day of recreation was computed to be \$0.26 (Kraynick and Stoevener 1981). Finally, in a study by Daubert and Young on the Poudre River of Colorado, the marginal value of water was estimated at various rates of instream flow. In this study, late season flows (i.e., September) had estimated values of \$10.54 and \$7.22 per acre-foot for

recreational and agricultural users, respectively (Daubert and Young 1981).

After carefully considering these and other studies that attempted to place a value on recreation and other water-related activities, it was decided that the work of Sutherland would be used.

One additional recreation activity -- moose hunting -- and the moose habitat that would be flooded if the dam were constructed had to be considered. Because data on the moose population were incomplete, a highest value scenario was developed. Using hunting permit information from DFWP and moose hunting expenditure information from Wyoming, a value for moose hunting was computed (Peterson 1982, State of Wyoming 1980).

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